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Invited Review: Role of livestock in human nutrition and health for poverty reduction in developing countries^{1,2,3}

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ABSTRACT: Livestock keeping is critical for many of the poor in the developing world, often contributing to multiple livelihood objectives and offering pathways out of poverty. Livestock keeping also affects an indispensable asset of the poor, their human capital, through its impact on their own nutrition and health. This paper outlines the linkages between livestock keeping and the physical well-being of the poor, and examines a number of commonly held beliefs that misrepresent

livestock development issues related to these linkages. These beliefs limit the scope of intervention programs to promote livestock and limit their potential contribution to poverty reduction. Recognition of the complexity of the role livestock play in household decision-making and of the opportunities foregone due to these misconceptions can enhance the ability of livestock to contribute to human well-being in the developing world.

Key words: developing countries, human health, human nutrition, livelihood, livestock, poverty

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INTRODUCTION

Through the millennia, animal-source food (ASF) has played a critical role in human development, including early contributions to the evolution of bipedal locomotion and the development of a larger brain (Mil-

ton, 2003). Later, domestication of animals and plants helped stabilize food supplies contributing energy for social development. Diamond (2002) popularized the argument that close contact with livestock differentially improved human immunity to zoonotic diseases, in turn providing advantages to some cultural groups. Today, livestock are well positioned to continue contributing to social transformation as a strategic asset of poor populations.

Livestock development efforts in lower-income countries are primarily intended to generate income and meet the growing demand for ASF. These efforts often give priority to technologies that maximize the productivity of individual animals, which may not be appropriate in the developing-country context. Hoffman et al. (2003) questioned the appropriateness of this strategy for Asia, noting examples of introduced animal breeds that were poorly adapted to the needs and constraints of poorer smallholder producers. The authors highlighted several other misconceptions (mis-)guiding the design of livestock development interventions. In this paper, we focus on the benefits that livestock provide for poverty reduction through better human nutrition and health. One objective is to describe the complexity of the livelihood strategies used by the

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²The Council of Science Editors (www.councilscienceeditors.org) has organized a Global Theme Issue on Poverty and Human Development for release in October 2007. Science journals throughout the world will simultaneously publish papers on this topic of worldwide interest to raise awareness, stimulate interest, and stimulate research into poverty and human development. The Global Theme Issue is an international collaboration of journals from developed and developing countries. This review represents our contribution to this important global effort.

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poor, the role of livestock, and their linkages to nutritional and health status. A second objective is to explore a number of misconceptions that hamper efforts to capitalize on the nutritional and health benefits that livestock can provide. We employ the perspectives of multiple disciplines, including animal science, economics, epidemiology, and public health. With respect to public health issues, we address both health determinants (e.g., poverty, inequality) and specific risks (e.g., zoonosis vectors, food-borne disease), emphasizing a “harm reduction” approach.

LIVESTOCK KEEPING AND THE POOR IN THE DEVELOPING WORLD

Livestock are ubiquitous in poor communities across the developing world. An estimated two-thirds of resource-poor rural households keep some type of livestock [Livestock in Development (**LID**), 1999]. Similar information for poor urban households is scarce, but a recent survey in 2 cities in Nigeria found that more than one-half of all urban households were keeping livestock; the highest rates were found in the most densely populated, lower-income areas [J. Olowoye and T. F. Randolph, International Livestock Research Institute (**ILRI**), unpublished results].

The livestock-keeping systems practiced by the poor have productivity per animal or land unit well below those in the industrialized countries. There are many reasons for this pattern of lower productivity. Smallholder management systems are typically low- or no-input, letting animals forage for themselves, feeding on plants or waste that otherwise would not be used. In many cases, relative prices of feed and livestock products provide insufficient incentives to use purchased inputs to develop intensive production systems (e.g., milk to feed price ratios of 1:1 in the Brazilian Amazon; Rueda et al., 2003). The poor often keep a mix of different species, trading off specialization for better protection against risks. Livestock systems of the poor reflect the resource constraints that they face (e.g., financial, access to information and services, and landlessness), as well as their varied reasons for keeping livestock, which include the following:

Producing Food. Livestock kept by the poor can produce a regular supply of nutrient-rich ASF that provide a critical supplement and diversity to staple plant-based diets (Murphy and Allen, 2003). This is particularly true for milk and eggs, which can help mitigate the effects of often large seasonal fluctuations in grain availability (Wilson et al., 2005). In many systems, slaughtering animals for meat is infrequent, though, occurring only when animals become sick or unproductive, or for exceptional occasions such as ceremonies or hospitality (Scoones, 1992).

Generating Income. In some cases, the household owns livestock for the express purpose of producing for the market. In other cases, sales may be occasional

to meet an urgent need for cash, such as paying school fees or medical costs (Kitalyi et al., 2005).

Providing Manure. Livestock waste is often an important input for maintaining soil fertility, and so contributes to greater crop production for food and income (Powell et al., 1998). In some areas, dung is also used as a fuel (Wilson et al., 2005). Dung for fertilizer, fuel, and building material is often a marketable commodity.

Producing Power. In many mixed crop-livestock systems, larger animals function as farm equipment, providing traction power for transportation and crop production, and to be hired out as well (Powell et al., 1998).

Serving as Financial Instruments. The poor often do not have access to standard financial markets, including banks. Livestock offer an alternative for storing their savings or accumulated capital as a “living savings account” that, although not without risk, provides a reasonably robust hedge against inflation (Doran et al., 1979; Bosman et al., 1997; Moll, 2005). Moreover, they can be sold and transformed into cash as needed and so also provide an instrument of liquidity and consumption smoothing. Similarly, keeping livestock is considered an alternative form of insurance, providing the family with assets that can be sold in times of crisis (Hoddinott, 2006).

Enhancing Social Status. Enduring cultural norms in many societies place considerable value on livestock as an indicator of social importance within the community, either based on the size of a family’s livestock holdings, or in their sharing of livestock with others, to strengthen social bonds, including the use of livestock as dowry or bride price (Ferguson, 1994; Kitalyi et al., 2005). Higher social status may translate into access to or authority over a broader base of resources in the community.

The multiple species kept by a household address these different objectives, sometimes concurrently. Thus, management does not necessarily focus on maximizing productivity from the individual animal or herd. Economists have valued the diverse contributions to help understand this apparent inefficiency. For example, Moll (2005) has suggested an approach for valuing livestock as financial instruments and for social status and demonstrates how these roles explain why Zambian livestock holders keep cattle well beyond the optimal age for commercial slaughter. Similarly, a recent study found off-take to represent less than 15% of the annual value generated by keeping cattle on smallholder farms in the cotton-growing zone in West Africa; the primary benefit was instead animal traction, accounting for two-thirds of the total value (Affognon, 2007).

The multiple objectives for keeping livestock suggest that it is misleading to view livestock as a conventional, independent production activity. Rather, livestock activities are integrated within household production and consumption decisions, making the role

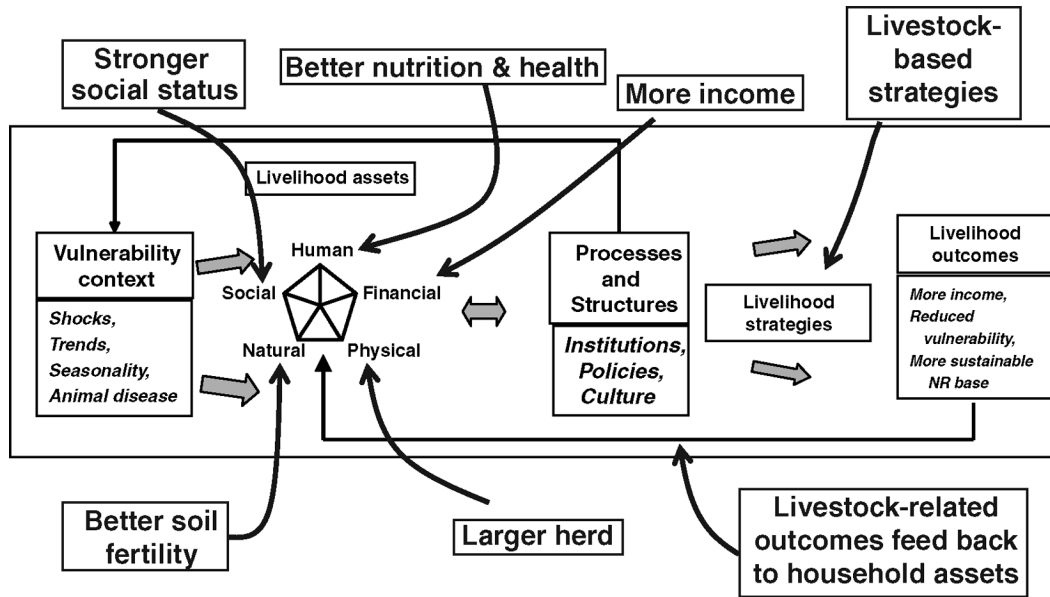


Figure 1. Sustainable Livelihoods Framework (Carney, 1998) with contributions of livestock to strengthening the asset base. NR = natural resources.

that animals play in household well-being complex. Conceptual frameworks such as the Sustainable Livelihoods framework (SLF; Carney, 1998) can be helpful to understand this complexity and to provide insights about the role of various types of household assets, with a focus on livestock, in the well-being of the poor. The SLF focuses on the role that various types of household assets play in mitigating risks, the development of livelihood strategies, and the resulting well-being of the poor (Figure 1). Starting from the left in Figure 1, the household is seen as facing constant threats from a wide range of possible biophysical and socio-economic shocks. This defines the vulnerability context for the household. Given this context, the household derives its livelihood to varying degrees from 5 key capital assets: human (based in part on nutrition and health), financial, physical, natural, and social. Households devise their livelihood strategies depending on their asset base and the risks they face, but this is conditioned by their institutional environment (public and private sector structures, policies, culture, and society's rules for behavior). Practicing the selected livelihood strategies leads to a range of outcomes that, if successful, feed back to strengthen the household's asset base.

In the SLF, livestock are a critical physical asset that can improve the stock or quality of each of the key household assets, reducing vulnerability, broadening livelihood alternatives, and improving outcomes. Selected connections between livestock and the various types of capital are illustrated (Figure 1). The use of manure as a soil fertility amendment can increase natural capital. Livestock ownership can enhance social capital. A larger herd constitutes an increase in physical capital, and better nutrition and health de-

rived from livestock improve human capital. The mechanisms by which livestock influence livelihood assets are those cited above as reasons for keeping livestock. Although simplified, the key capital assets in the SLF are obviously interrelated (e.g., better health can lead to greater incomes and larger herd size).

The ILRI identifies 3 main livelihood strategies by which livestock can be used to pull households out of poverty (ILRI, 2003). Termed "pathways out of poverty," the first pathway focuses on how livestock help to secure the household's asset base by providing access to more reliable flows of the benefits noted above. This capacity may help buffer the household, allowing it to bear risks associated with developing other income-generating strategies. The second pathway represents the livestock development scenario in which specialization and intensification increase the productivity of livestock, in turn increasing household incomes and promoting accumulation of other assets. The final pathway involves improving access to market opportunities (e.g., opening new markets, getting better prices) that increase the profitability of livestock activities and create incentives to increase production and sales.

The SLF framework provides a stylized overview of how livestock can contribute to reducing poverty in resource-poor households. We present it to highlight the complexity of the context in which livestock can influence household-level poverty. Within this context, we now narrow our focus to the linkages between livestock and human health and nutrition in poor communities and consider the specific dynamics by which livestock keeping can strengthen these aspects of the human capital component of the household's asset base.

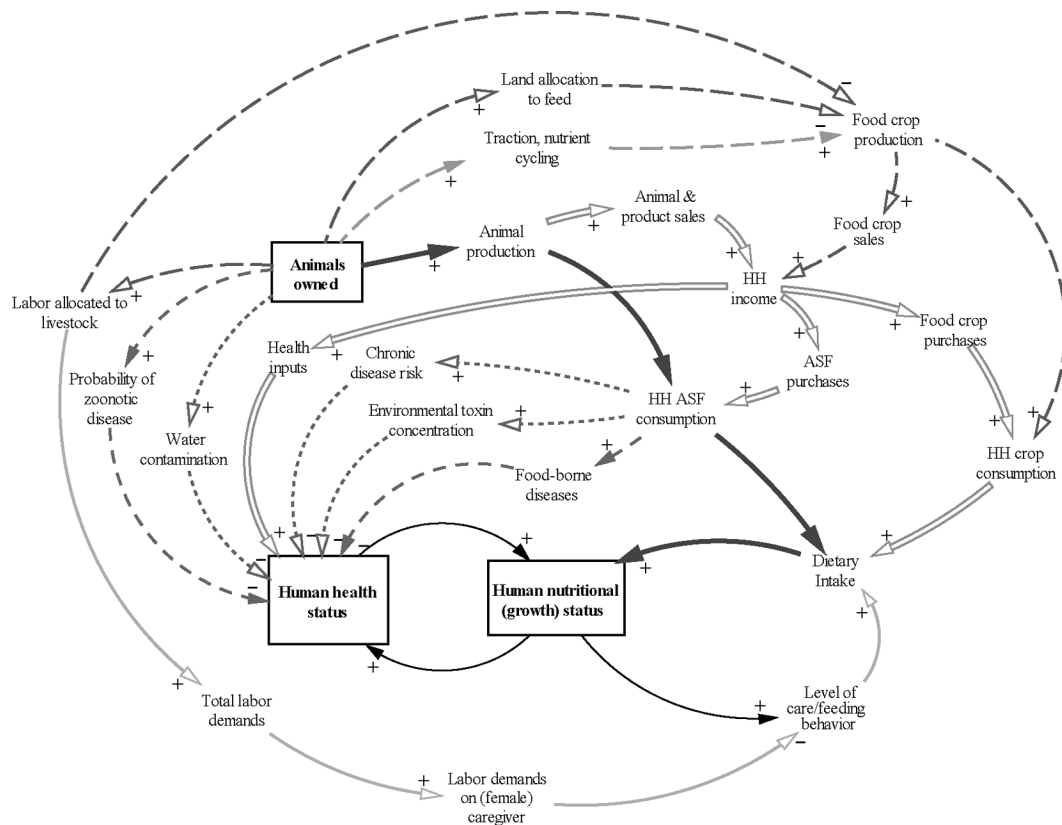


Figure 2. Hypothesized causal linkages between livestock keeping and human nutrition and health outcomes among the poor (adapted from Nicholson et al., 2003). ASF = animal-source food; HH = household; arrows indicate different causal linkages and are defined in the text.

LINKAGES TO HUMAN NUTRITION AND HEALTH

The dynamic between livestock keeping and the physical well-being of the family is complex. Figure 2 presents various hypothesized causal linkages between the household livestock activity (animals owned, indicated with a box) and individual household members' nutritional and health status (also indicated with boxes in Figure 2). Arrows indicate hypothesized causality between variables, and the plus or minus sign indicates the hypothesized direction of influence. For example, the arrow between the variables "animals owned" and "animal production" indicates that owning more animals would increase production. A synergistic relationship is shown between human health and nutritional status.

Keeping livestock influences human nutritional and health status through numerous multiple-link causal chains. In one chain (thick solid arrows in Figure 2), owning animals increases the amount of ASF available, which can increase ASF consumption, dietary intake, and nutritional status. Other chains (thick open arrows in Figure 2) indicate that animals owned increase animal production, animal and livestock product sales, and household incomes. Income from the sale of livestock products can be used to purchase

ASF or other foods, and allow more or better quality healthcare services or products to be purchased by the household. Animals owned are also hypothesized to provide traction and nutrient cycling services that increase food crop production (light dashed arrows with solid arrowhead in Figure 2), possibly increasing crop sales, household income, and household food crop consumption.

The hypothesized causal chains discussed above imply a positive effect of livestock ownership on human health and nutritional status. However, livestock also can worsen human health and nutrition through a variety of linkages. First, allocation of household resources such as land and labor to livestock can, under some circumstances, reduce production, consumption, and sales of other food (dashed arrows with open arrowhead in Figure 2). This can have an offsetting effect on household food consumption and income. Second, zoonotic disease associated with livestock keeping can be transmitted from livestock or their products to family members, as can other food-borne diseases often related to ASF consumption (dashed arrows with solid arrowhead in Figure 2). Three other chains (dotted arrows with open arrowhead in Figure 2) also result in disease, but indirectly either through environmental contamination by livestock waste (especially of water resources), concentration of environmental toxins in

ASF, or by contributing to chronic diseases such as cardiac disease associated with overconsumption of certain ASF. Labor allocated to livestock can increase total household labor demands, particularly for females, and reduce the time and quality of care and feeding of young children, negatively influencing their nutritional status (thin arrows with open arrowhead in Figure 2).

Finally, the linkages representing the interaction between nutritional and health status can improve or worsen health depending on other factors. If keeping of livestock leads to poor health, then nutritional status is likely to be compromised by reduced appetite or poor absorption of nutrients. Importantly, this effect can also work in reverse: improved nutritional status due to ASF consumption will likely bolster immune resilience and health. A key implication of this diagram is that the multiple causal chains involved make it difficult to determine through logic alone what the impacts of livestock ownership on human health and nutrition will be in a given setting.

Researchers at Cornell University, the Global Livestock Collaborative Research Support Program (CRSP), and the ILRI developed the above diagram (Figure 2) to better visualize these various hypothesized causal chains and to structure a review of the available evidence regarding the relationships at the household or community level between livestock keeping and human nutrition in developing countries. Because the focus of this review is the household or community, the diagram ignores what are likely to be important multiplier effects within the economy and the longer-term macroeconomic benefits as better-nourished children become more intelligent, healthier, and more productive adults. The review is ongoing, but some key lessons are emerging. First, although there is a considerable body of evidence about many of the individual linkages along the various hypothesized chains, there have been few appropriately designed studies that have assessed the overall net effect of livestock keeping on human health or nutrition. It is likely that the relative importance of the various causal chains associated with beneficial and harmful effects will vary considerably depending on the specific production and market system context, and so the net empirical impacts would vary. Nonetheless, the general pattern from the evidence reviewed suggests that livestock keeping is associated with a generally positive, although modest, impact on nutritional well-being in the household (Leroy and Frongillo, 2007). However, it appears that, on average, both the positive and negative influences of livestock keeping become diluted as they pass through the links along the chain. A resource-poor household may directly consume the ASF produced by its livestock holdings, but the output is so modest and infrequent, or is not fed to the household members who would benefit the most, that it becomes difficult to discern its impact.

Overall, then, the linkages in the diagram (Figure 2) help us appreciate that the effect of livestock keeping in resource-poor communities is mediated through a complex set of interacting, and sometimes counteracting, processes. Having established this context, we devote the remainder of this paper to examining a series of commonly held misperceptions regarding the causal chains in Figure 2 that most affect the health of the poor—nutrient intake, zoonotic disease, and foodborne disease. These misperceptions are of 2 types: 1) lack of basic understanding of an issue (such as the importance of ASF or disease), and 2) erroneous beliefs on the best way to manage nutrition and health problems. These views, when applied to the poor in the context of lower-income countries, are sufficiently frequently misconstrued that we set them out as “myths” that constrain livestock keeping’s potential to more effectively contribute to reducing poverty.

Myth 1: Promoting Animal-Source Food Consumption Among the Poor Will Do More Harm than Good

Over the past 2 decades, livestock and their products have received negative publicity in higher-income countries due to health and environmental concerns. Livestock production, for example, is assigned responsibility globally for 18% of current greenhouse gas emissions in CO₂ equivalents (Steinfeld et al., 2006). Highly publicized outbreaks of emerging diseases, such as bovine spongiform encephalopathy (BSE) and avian influenza have contributed to consumer nervousness about livestock products, as has the continuing debate about the association between the saturated fats and cholesterol found in ASF and chronic disease, especially heart disease and cancer. Popkin and Du (2003) argue pointedly that the rapid increases in ASF consumption and associated health problems as incomes rise in China specifically demonstrate the negative health consequences of over-promoting the ASF sector in middle-income countries.

Such views might make international agencies and donors hesitant to be seen promoting livestock to alleviate poverty. Although the health concerns associated with ASF are certainly valid, they need to be balanced by an understanding of the much larger and more immediate benefits that ASF provide to the poor. Malnutrition remains a large and persistent problem in the developing world. Many of the poor in lower-income countries suffer from micronutrient deficiencies because of diets based mainly on cereals. These diets are not only often low in several micronutrients (Neumann et al., 2003), but they are also important sources of phytic acid and dietary fiber, which inhibit the absorption and (or) retention of nutrients such as iron and zinc (Gibson, 1994a). Some 820 million people were chronically undernourished in the period from 2001 to 2003, representing 17% of the total developing world population (FAO, 2006). Short-term effects include

Table 1. Micronutrients provided by animal-source foods (ASF)

Nutrient	Sources	Consequences of deficiency	Relevance (groups affected by deficiencies)
Vitamin A	Dairy, liver, fish-liver oil, egg yolk (Latham, 1997)	Growth faltering, impaired development, impaired vision, blindness, impaired immune system, death, maternal mortality (Ruel, 2001; West, 2004)	140 million young children, 7 million pregnant women (UN System Standing Committee on Nutrition, 2004)
Iron	Meats and fish contain heme iron (facilitates non-heme iron absorption; Mosen, 1988)	Young children: impaired growth, cognitive development, and immune function. School-aged children: impaired school performance Adults: lowered work capacity, maternal mortality (Ruel, 2001)	4 to 5 billion people (UN System Standing Committee on Nutrition, 2004)
Zinc	Meats and (shell)fish (Hotz and Brown, 2004)	Pregnancy complications, low birth weight, impaired immune function, maternal and infant mortality and morbidity, growth faltering in infancy and childhood (Gibson, 1994b)	Estimated as 1 in 2 persons globally being at risk (Brown et al., 2001)
Calcium	Dairy and fish (if consumed with bones) (Weaver, 2001; Roos et al., 2003)	Nutritional rickets (Pettifor, 2004)	No global estimates, but rickets seems to be reappearing (Wharton and Bishop, 2003)
Riboflavin	Dairy, organ meats, eggs (McCormick, 2000)	Stunted growth skin lesions, soreness and burning of the lips, mouth and tongue, burning and itching of the eyes, photophobia, corneal vascularization, cheilosis, angular stomatitis, glossitis, anemia, and neuropathy (McCormick, 2000)	Good global estimates unavailable (estimated 90% of all adults in China deficient; McCormick, 2000)
Vitamin B ₁₂	ASF are only source except some algae (Shane, 2000)	Megaloblastic anemia, demyelinating disorder of the central nervous system (Stabler, 2001)	Data are not available on global prevalence, but high prevalence of vitamin B ₁₂ deficiencies reported in many countries (Allen et al., 2001; Murphy and Allen, 2003)

lower physical growth and frequent infections. Undernutrition has long-term effects on cognitive development, school performance, and achievement. An additional tragedy relates to negative intergenerational effects: undernutrition early in life increases likelihood of having a low-birth-weight infant. This lowers human capital development and productivity in developing countries, constraining macroeconomic performance and potential for economic growth (UN/IFPRI, 2000; Neumann et al., 2002; Demment et al., 2003).

Animal-source foods are particularly appropriate for combating malnutrition and a range of nutritional deficiencies. First, ASF are energy-dense and good sources of protein and a large number of key micronutrients, deficiencies of which have severe consequences (Table 1). Thus, ASF can measurably enhance nutritional quality in diets, especially for nutritionally vulnerable groups such as young children and pregnant and lactating women. Second, in many cases, nutrients in ASF (e.g., iron and zinc) exhibit greater bioavailability than those from plant sources. Moreover, meat and fish are effective dietary enhancers of non-heme iron absorption. Third, in undernourished populations, ASF consumption is very low, in both absolute and

relative terms [see, for example, the comparative intake levels for Kenya, Mexico, and the United States reported by the Council for Agricultural Science and Technology (CAST), 1999]. At these levels, moderate increases in ASF consumption provide critical nutritional benefits with little potential of crossing the threshold of significant risk for chronic disease. The available evidence indicates that for the diets typical of most poor in developing countries, the beneficial role of meat outweighs the uncertain association with cancer (Biesalski, 2002; Hill, 2002) or cardiovascular disease (Glew et al., 2001). Finally, the high nutrient density of ASF makes them attractive as a food-based intervention for populations that have difficulty consuming large volumes of food, including very young children (who have limited gastric capacity relative to their high nutritional requirements during this stage of rapid growth), and people living with HIV/AIDS whose nutritional requirements can double while at the same time they suffer poor appetite due to secondary digestive tract infections and nausea (Roubenoff, 2000). Efforts are needed to raise awareness among policy makers and researchers about the benefits of ASF consumption for the poor and the negligible risks

of negative (nutritionally mediated) health impact (and similarly, the small negative environmental impacts of livestock kept by the poor and relative to the much larger societal benefits of livestock keeping for their livelihoods).

Myth 2: Livestock Keepers Are Livestock Eaters

Smallholder livestock development projects sometimes specify improvement of household-level food and nutritional security as a primary objective, implying that increased household livestock production translates directly into increased ASF consumption and improving nutritional status. This is simplistic. As noted above, our review suggests that livestock interventions are generally associated with greater ASF intake and better nutritional well-being, but as pointed out by Hoffman et al. (2003), introducing livestock activities or increasing productivity of existing livestock will not necessarily mean that households consume the additional ASF produced and display better nutritional outcomes. Such livestock interventions typically involve market-oriented management systems that are more intensive and more dependent on purchased inputs. In these systems, a significant share, if not most, of the production will be sold rather than consumed on-farm.

As noted in Figure 2, the income generated may be associated with increased household food expenditures, and with improved household food availability and diet quality. However, previous research on the impact of cash crops has shown that this income-mediated effect on nutritional security may become considerably diluted because only a portion of the income gain goes to food expenditures, and households may choose higher quality (and more expensive) foods that do not improve substantially their nutrient content. Moreover, the benefits may not be shared equally among household members. Diets of young children and pregnant and lactating women in particular may not improve as income and food expenditures increase (von Braun and Kennedy, 1994). Thus, if improved nutritional security is an objective of livestock development, interventions must be designed accordingly, rather than assuming the desired impacts will occur automatically. One approach is to complement livestock development activities with targeted health and nutrition interventions as well as behavioral change and communications strategies to improve intra-household allocation of resources and timely use of health and nutrition services. To our knowledge, no systematic analysis of livestock interventions exists to guide such design. Although we have empirical evidence regarding the net association between livestock interventions and human nutritional status, no research has been conducted to date to understand the underlying dynamics, thus limiting our ability to design interventions that are more effective. Our ongoing review of livestock interventions suggests that their

integration into a broader range of food production activities, targeted to women and complemented with nutritional education, may generate more consistently positive nutritional benefits.

Myth 3: Livestock Keeping Is an Inefficient Strategy for Feeding the Poor

Citing high grain-to-ASF conversion ratios, some authors have argued that increasing pressure on world food supplies will need to be addressed in part by reducing ASF in the global diet if global nutritional requirements are to be sustained (Kendall and Pimentel, 1994; Goodland, 1997). Goodland (1997), for example, noted, "1 acre of cereals can produce twice to 10 times as much protein as an acre developed to beef production." Echoes of this are sometimes heard in policy discussions regarding smallholder livestock development, suggesting that priority for scarce land resources of the poor be focused on food crop production before considering using land for feed crop or livestock production.

A CAST Task Force undertook a comprehensive review of the evidence for this argument (CAST, 1999) and, for selected countries, computed gross efficiency indices of conversion of diet energy and protein to livestock products and returns on human-edible inputs in those products (calculated as units of human-edible outputs per unit of human-edible input). The results for Kenya and Egypt (representing developing countries) clearly demonstrated the negligible competition between livestock and people for food resources given use of marginal lands and crops for livestock feed and forage. Under current (largely extensive) livestock production systems, particularly those practiced by the poor, livestock clearly offer the most efficient utilization of resources that would otherwise go unexploited, such as the use of organic wastes to feed livestock in urban areas.

Myth 4: Conventional Public Services Alone Can Most Effectively Control Zoonoses and Food-Borne Disease

Livestock nourish the poor, but at the same time may expose the poor to zoonoses and food-borne disease (FBD). As highlighted in a recent World Health Organization (WHO) report, the poor "bear a disproportionately high share of the burden of (zoonotic) disease" because of their close contact with livestock in unsanitary conditions, the lower likelihood that they will get the needed healthcare, and the dual effects on both their health and their animals (WHO, 2006). Poor control of zoonoses and FBD can therefore undermine the effective use of livestock for poverty reduction. A first misconception on the control of zoonotic disease is that public services alone can control the zoonotic diseases affecting the poor in the developing world. Transmission cycles for these diseases that result in

human illness can be effectively broken by a range of measures such as animal vaccination, test-and-slaughter, vector control, use of preventive and curative drugs, milk pasteurization, meat inspection, risk analyses in the market chain, and consumer education. National veterinary and public health agencies in industrialized countries successfully apply these types of measures as control strategies, but in developing countries few such strategies have been sustainably implemented (Blancou et al., 2005). Weak public-sector control can be attributed in part to resource constraints because funding for human health and livestock services has been declining over the past several decades. In addition, there is an inherent challenge of providing information and services to highly dispersed and heterogeneous livestock producers and markets characterized by poor roads, modest telephone and television coverage, and long distances (McDermott et al., 1999). For this reason, many resource-poor countries are unable to achieve satisfactory coverage and quality of public delivery even when programs are better funded (Mills et al., 2004). Moreover, zoonosis control has both public- and private-good characteristics [see Holden (1999) for a detailed analysis]. Responsibility for control measures and surveillance of livestock zoonoses has been increasingly shifted to producers, processors, and distributors of livestock and livestock products, with the government role limited to regulatory surveillance (FAO, 1998; Perry et al., 2001; Ahuja, 2004). This trend toward privatization has generally overlooked the needs and constraints of poor livestock keepers (LID, 1999; Heffernan and Misturelli, 2000; Peeling and Holden, 2004).

Public services will certainly continue to play an important role in zoonosis control, but if control is to be effective, conventional strategies will need to be complemented and, in some cases, replaced by alternative strategies more appropriately adapted and targeted to the poor. Several different versions of contracting with private operators have been proposed and tested (Perrot, 2006). Experiments with public-private initiatives, such as the Global Alliance for Livestock Veterinary Medicines (GALVmed), are ongoing, but such arrangements still need to prove their sustainability (Lorenz, 2007). Strong producer organizations can offer an efficient tool for delivering zoonosis control to poor livestock keepers. In many countries, however, farmer cooperative structures are making a difficult transition from an era of state control to autonomous management. Community (animal) health workers who work in partnership with the professional segments of the private and public sectors have been successful in providing basic health and veterinary services to marginalized and remote communities, but legal arrangements for them are still lacking in several countries (Catley et al., 2004).

Strengthening these types of systems to implement zoonosis control, supported by mass information, education, and communication programs (Hunt, 2003),

may offer the most effective and sustainable option for reducing risk for the poor, but such alternative systems are still insufficiently implemented. In response to the highly pathogenic avian influenza outbreaks in Africa in 2006, analysts urged the rebuilding of public services in the affected countries to mimic the approach of the industrialized countries. However, this strategy risks recreating ineffective bureaucracies, so investment should be oriented instead to promoting sustainable alternative approaches.

Myth 5: Sectoral Specialization Is the Most Efficient Approach for Control of Zoonoses

Medical and veterinary sectors have developed their own approaches to zoonoses consistent with their established professional conventions of describing, identifying, and controlling the respective human and animal aspects of zoonoses. Historically, they have worked independently and each sector has developed distinctive expertise and strategies. Collaboration across the 2 sectors is discouraged by institutional mandates and professional biases that create high transaction costs. This compartmentalization has hampered successful control of zoonoses both by obscuring the true impact of disease and by increasing the cost of its control. Because the impacts of zoonoses on human health, livestock production, and trade are typically considered separately, the full costs are not calculated, and control efforts are not rationally allocated. Roth et al. (2003) demonstrated that if the costs of proposed vaccination against brucellosis in livestock in Mongolia were allocated to all sectors in proportion to the benefits, control was profitable and cost-effective for both the livestock and the public health sectors.

Overcoming sectoral bias and promoting integrated cross-sectoral approaches would raise awareness about the impact of zoonoses both generally and, more specifically, on the poor, and would lead to better designed and implemented control strategies (Zinsstag et al., 2005). The Cysticercosis Working Group for Eastern and Southern Africa, which brings together medical, veterinary, and animal production scientists and professionals to coordinate research and development activities targeting this zoonosis, offers an example of institutional innovation promoting cross-sectoral collaboration for research targeting a specific disease (Boa et al., 2003).

Myth 6: We Know Which Zoonoses Matter to the Poor

Ideally, national and international public health and veterinary agencies would allocate their efforts to control zoonoses based on evidence generated regarding the burden of these diseases relative to other human or animal health concerns. In practice, priority zoonoses from the perspective of the poor likely receive less attention and resources than they merit (Perry et

al., 2005). Although this is due in part to the low visibility of zoonotic disease, an additional problem is the lack of quantitative data needed to estimate importance. Surveillance and monitoring systems are weak in many countries, and where they do operate, the poor have little access to them. The poor also make less use of formal services that report diseases. Second, zoonoses may be systematically underreported because of diagnostic tools that are ill-adapted to field conditions and difficulties in distinguishing from other common diseases, reflecting low awareness of the diseases by both professionals and the public (WHO, 2006). Third, impacts on human health and livestock production are rarely aggregated due to sectoral compartmentalization. Fourth, awareness among researchers and professionals of zoonoses and their importance may reflect a Northern bias acquired during professional training and overextrapolating from better-characterized disease situations. Finally, few attempts have been made to assess the impacts of zoonoses on the poor. The effects are probably larger because of the greater risk of infection faced by the poor and the wider range of potential livelihood impacts, including bearing the dual burden of disease on their health and their livestock (Perry et al., 2002; WHO, 2006). Applications of participatory techniques have begun to generate information to address these gaps (Heffernan and Misturelli, 2000). Because zoonoses affecting the poor are not prioritized, health and veterinary services typically under-invest in them. In the case of emerging zoonoses that benefit from publicity and perceived threat to higher-income countries, over-investment can also be a problem. Emergency investments may not lead to the most effective reduction of zoonosis disease burden, but rather to unsustainable technology transfer. The expression “neglected zoonotic diseases” is now used more frequently, and the establishment of a program at WHO devoted to neglected zoonoses reflects growing recognition that disease priorities for the poor may not yet be correctly identified.

Myth 7: Food Safety Is Not a Priority for Poor Countries

With the high numbers of people suffering from protein-energy malnutrition as discussed previously, food safety is sometimes seen as taking second place to food security in poor countries. In reality, in higher-income countries food has never been safer (Knox, 2000), yet for the poor in developing countries, FBD is frequent, important, serious, and underappreciated. Estimates are that biological contamination causes 2 billion illness episodes annually (Flint et al., 2005), with as much as 70% of diarrhea episodes among children under 5 yr linked to biologically contaminated food (Mortarjemi et al., 1993). Moreover, life-threatening or long-term conditions such as ankylosing spondylitis, arthropathies, renal disease, cardiac dysfunction, neurological disorders, abortions, and developmental ab-

normalities may be sequels of FBD and may represent a greater overall health and economic burden than the acute disease (Lindsay, 1997). Factors that make poor countries more vulnerable to FBD include greater proportions of vulnerable people (young, immunosuppressed, or malnourished), a greater range and higher prevalence of pathogens, environmental conditions that favor pathogen survival and growth, less food-preservation infrastructure, inadequate food-safety systems, and lack of capacity for detection and management of food-safety problems.

Food-borne disease has a double impact on the livelihoods of the poor. Already a direct cause of sickness and death, it increasingly creates exogenous shocks to livelihoods of farmers and others in the food value chain when it leads to product bans or panics consumers and reduces demand for livestock products. The recent outbreak of Rift Valley Fever in East Africa led to large decreases in consumption of milk and meat. In eastern Kenya, most butchereries were forced to close because of lack of customers, and the price of cattle was 50% less in affected areas compared with unaffected areas (New Agriculturist, 2007). Avian influenza is another case in point. In Bangladesh, poultry consumption decreased by 70% before a single human or avian case was reported there, and in Vietnam, financial losses ranging from \$70 to \$108 per farm were attributed mainly to the decrease in consumer demand for poultry (Rushton et al., 2005). Food-borne disease is, therefore, a major contributor of vulnerability of the poor to both disease and poverty. As such, improving food safety must go hand in hand with improving food availability and access as part of a more holistic approach to food security.

Myth 8: Food-Safety Standards Are Blocking Poor Farmers from the Big Market Opportunities

Another myth is that food-safety standards currently inhibit efforts to reduce poverty. The argument is that safety standards act as barriers that exclude poor livestock farmers from both higher-end domestic markets and global trade. There is good evidence that increasing private standards in domestic markets due to growth of large-scale retailers (e.g., supermarkets) have created massive displacement of small producers in some middle-income countries (Gutman, 2002). For example, rapid growth of supermarket sales in Brazil was associated with the exit of 60,000 farmers from milk production and a 55% increase in the average farm size (Reardon et al., 2002). As supermarkets continue to consolidate, vertically integrate, and push more responsibility for standards down the supply chain, this trend is expected to continue (Brown, 2005). But is it of any relevance to the poorest countries of greatest concern from the perspective of human development?

Evidence indicates that caution must be used in extrapolating trends to the poorest countries. In sub-

Saharan Africa, supermarkets account for less than 5% of urban food expenditures and will remain a minority food supplier for the foreseeable future (Traill, 2006), especially for fresh produce, such as the bulk of ASF. Even in Nairobi, with one of the most developed supermarket sectors in sub-Saharan Africa outside of South Africa, only 8% of meat purchases (vs. 60% of staples) are made in supermarkets (Ayieko et al., 2005). And in poor countries specifically, there seems to be weak association between supermarkets and safer food. Studies in East Africa (Omoro et al., 2005) and India (D. Grace, ILRI, unpublished results) have shown that similar proportions of samples of supermarket and informally marketed milk were substandard.

A closely related concern is that export markets will exclude poor farmers on food safety grounds, but the evidence suggests first that livestock export is of peripheral importance to the poorest and second, that food-safety standards are not a critical constraint to export. Several recent studies have unambiguously shown that livestock exports remain of minimal importance to the poorest countries (Nelson, 2005; World Bank, 2005; Tambi and Bessin, 2006). Globally, 90% of livestock and livestock product transactions are domestic, and international trade is dominated by a small number of players. For example, just 9 countries account for 96% of beef exports. Africa exports about 1% of the world's total volume of meat and milk and this proportion has been declining in recent years; most countries remain net importers. Even where livestock exports are important, food-safety standards are either irrelevant or an easily surmountable barrier. First, exports are mostly to other developing countries that are unable to establish, monitor, or enforce standards (Nelson, 2005). Second, where standards are applied, compliance costs are surprisingly low [e.g., 1% of the total value of shrimp exports from Nicaragua (Cato et al., 2005)] and may be offset by other benefits, such as acting as catalysts for trade, growth, and poverty reduction. Farmers consider many other issues, ranging from basic infrastructure to social and political stability, to be greater constraints to exports [International Federation of Agricultural Producers (IFAP), 2000]. Thus, although food-safety standards are an important concern for rich countries and higher-income developing countries, among the poorest countries their relevance currently is minimal and, as such, may not be a good area in which to invest scarce research and development resources. Food safety is a high priority for the poorest countries, but food safety standards are not.

Myth 9: Elimination of Food-Borne Disease Is the Only Acceptable Objective

Consumers, the media, and politicians often demand absolute safety, whether in high-income or low-income countries, but setting a goal of zero risk is both unat-

tainable in the foreseeable future and unhelpful in encouraging appropriate management approaches. The epidemiological and institutional difficulty of controlling FBD is generally underestimated in developing countries. Epidemiologically, the most important FBD (i.e., salmonellosis, campylobacteriosis, coliosis, and listeriosis) are characterized by high prevalence and lack of symptoms in livestock, persistence in the environment, and lack of gross lesions on visual inspection of food, all of which make control difficult. These biological challenges are compounded by dysfunctional food-safety monitoring systems in many developing countries. Pervasive problems include confusion between quality and safety, excessive regulation, selective enforcement, lack of integration of food laws and regulations in the overall legislative system, multiplicity of responsible agencies, and the mismatch between the standards required in the countries of the Organisation for Economic Co-operation and Development (OECD) and in developing countries (van Veen, 2005).

But it is not just the feasibility; the appropriateness of controlling FBD must also be questioned. Food-safety policy currently fails to take into account other concerns, such as poverty reduction, equity, gender empowerment, and environmental protection, resulting in regulations that are infeasible in terms of enforcement and compliance and which penalize the poor. Examples include requirements that all milk be pasteurized or bans on the sale of street foods. Worse still, high formal safety standards may paradoxically decrease overall food safety by making informality more attractive (Azevedo and Bankuti, 2002). Pragmatic risk-based approaches, which use methods to identify and then mitigate risk at critical control points along the stable-to-table pathway, offer a better approach to managing FBD through their objective of an "appropriate" rather than "absolute" level of protection. Studies in East Africa indicate how this can counter the "zero-risk" mindset and change policy and practice to improve both food safety and farmer livelihoods (Omoro et al., 2005).

CONCLUSIONS

Livestock development interventions in lower-income countries typically have as their primary objective generating income for livestock-keeping households. Nevertheless, livestock can also be used to deliver critical micronutrients needed to enhance the nutritional status of household members and secure their most fundamental livelihood asset, their human capital, as a pre-condition for alleviating poverty. However, risks associated with zoonoses and FBD need also to be recognized, especially for vulnerable subpopulations. We contend that the impact of livestock on human health and nutrition has been largely ignored, and that it offers an unexploited opportunity for adding value to livestock interventions and improv-

ing their potential to reduce poverty. To achieve this requires a deeper appreciation for the complexities associated with the role that livestock play in the livelihood strategies of the poor and in household nutritional and health dynamics. It also means recognizing the context in which poor households operate, especially with respect to their participation primarily in informal markets and weak capacity in the public sector.

A few key lessons emerge from our review of livestock keeping and the nutritional and health status of the poor. We have discussed the limited awareness of the importance of the livestock–human health–poverty interface, as well as misconceptions about the management of livestock-related problems. Our lack of knowledge implies the need for carefully designed, empirical research, including environmental and social considerations, possibly combined with a systems modeling approach to untangle the complexity and enhance development of practical guidelines and best practices for livestock intervention design. Some lessons have already been learned and successes exist. For example, delivery gaps may be best filled by cross-sectoral approaches that integrate veterinary and public health. At the same time, we need to move beyond the conventional state-led provision of services and develop new institutional innovations and strategies that explicitly consider the needs of the poor. An overarching conclusion is the need for a systems perspective and poverty lens for research on livestock production and health in developing countries.

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