Can Livestock Production Ameliorate Under nutrition?

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SUMMARY

Humans have long depended on livestock as a source of food, in addition to providing power for cultivation and transport. As Diamond (1999) eloquently argued, the availability of appropriate wildlife for domestication was an important factor explaining why certain societies advanced more quickly than others, both by allowing the production of food surpluses and by exposing man to a range of zoonotic diseases that increased immunity. Today, an estimated two-thirds of the two billion poor living on less than \$2 day^{-1} in the world continue to depend directly upon livestock for their livelihoods (LDG, 2004). Research, such as that conducted at the International Livestock Research Institute (ILRI) and by the Global Livestock CRSP and livestock development investments seek to enhance the benefits that livestock can provide to the poor. However, the role that livestock can play in alleviating poverty is still not well understood. One argument for promoting livestock among the poor has been based on the perceived nutritional benefits keeping livestock can provide, whether through direct consumption of animal source foods by poor households or through improved diet and health permitted by income generated through the sale of the livestock and their products. In this paper, we review the evidence regarding these links between livestock keeping and human nutritional well-being.

The information compiled and conclusions drawn by the review are intended for two main audiences. The first is the research community. Conducting an inventory of what is known about the links between livestock keeping and nutrition will allow us to identify what we don't know, leading us to the priority knowledge gaps and challenges where increased research attention is merited. More specifically, the review was prompted by the need for ILRI to define its evolving research agenda on this topic. The second audience is the development community, which may benefit from improved guidelines for what type of livestock intervention might have the most favorable impact on the human capital of their targeted client groups. The review is meant to raise awareness of the need to carefully consider how different types of livestock-based interventions may be expected to achieve the intended goal of improving the well-being of the poor.

The key findings of this review are:

- Nutritional well-being is essential for economic growth, due to interactions between nutritional status and labor productivity. Because the impact of undernutrition (especially micronutrient malnutrition) is established early in life, it can have substantial long-term effects on human capital development and productivity. Therefore, addressing the micronutrient deficiencies in children is of primary importance

- Millions of people worldwide—and especially in low income countries—suffer from micronutrient deficiencies as a consequence of diets consisting of little more than staple foods such as rice or maize. Animal-source foods (ASF) are good sources of essential nutrients such as iron, zinc and vitamin A, and that many nutrients are better absorbed from animal source foods than they are from plant source foods. The potential contribution of ASF consumption to diet quality and nutrition is indisputable;

- Existing evidence suggests that interventions that promote livestock production and livestock ownership per se have generally positive impacts on the production of ASF, consumption of

ASF, overall dietary intake, nutritional status, and household incomes. The evidence is less widely available and less consistent with regard to the impacts of livestock on caregiver income, caregiver time allocation, maternal labor force participation, and incidence of zoonotic disease.

- Interventions with livestock integrated into a broader range of food production activities, targeted to women and those that include nutritional education components appear to result in more consistent positive nutritional impacts;

- Many of the existing studies of the linkages between livestock interventions or ownership and nutritional status allow only limited inference due to study design limitations. In view of the challenges of implementing controlled experimentation in agricultural production systems with livestock, most future research will need to be of the "comparative observational study" type. Future studies can be improved through various methods that help control for confounding factors;

- Based on an examination of outcomes for which there is reasonably adequate evidence, livestock-related interventions appear to satisfy the "do no harm" criterion with regard to nutritional status and therefore will be appropriate in certain development contexts. However, information about the relationships between livestock ownership and zoonotic disease incidence is insufficient to rule out the possibility of negative health and nutritional effects due to livestock. Additional attention to monitoring and evaluation components, consistent with the study design characteristics mentioned above, can improve both program effectiveness and future program design;

- Systems simulation modeling may be a useful tool for the conceptualization of the nonlinear dynamic systems that result in nutritional outcomes, and may aid in the identification of future research priorities.

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CHAPTER 1: INTRODUCTION

Undernutrition remains a problem of unacceptable magnitude in the developing world. One dimension of the problem is protein-energy malnutrition, which continues to affect large numbers of children and adults, particularly in sub-Saharan Africa (Latham, 1997). In addition, poor people often survive on monotonous plant based diets consisting of little more than staple foods such as rice or maize that are low in micronutrients and also reduce their absorption. As a result, billions of people suffer from micronutrient deficiencies. Undernutrition results in lower quality of life for the affected individuals and households, but also markedly reduces labor productivity and the potential for economic growth. Livestock production, defined here as production systems that include the use of domestic animals and aquaculture, has the potential to ameliorate multiple dimensions of the global undernutrition problem. However, the pathways by which livestock production can influence nutritional status are complex, and little is known about many of them. The overall purpose of this document is to summarize the available knowledge about the potential of livestock production to reduce or eliminate undernutrition, and to suggest both actions possible based on existing information and identify priority information needs to enhance the nutritional benefits of livestock production. Because undernutrition has serious implications for both children and adults, we review the literature related to both these groups, emphasizing one as appropriate to the discussion.

The basic pathways by which animal production can influence nutritional status include a) impacts on the consumption of animal-source foods (ASF) from a household's own production, b) impacts on household income from the sale of livestock products (income that may be spent on other foods or health-related items but need not be), c) impacts on productivity of cropping systems due to nutrient cycling or traction services provided by animals, d) impacts on the allocation of household labor among various activities, including caring for children, and e) impacts on human disease incidence from livestock keeping. Much of the research to date on the impacts of livestock production on nutrition has focused on the nutritional impacts of the consumption of animal-source foods (ASF) in low-income populations, with an emphasis on how ASF might reduce micronutrient malnutrition. It has long since been known that animal source foods are good sources of essential nutrients such as iron, zinc, vitamins A, and B_{12}, and that many nutrients are both more concentrated and better absorbed from animal source foods than they are from plant source foods. The potential contribution of ASF consumption to diet quality and nutrition is thus indisputable. Documentation of the benefits of ASF consumption using controlled experiments has been a necessary first step to understanding the linkages between livestock and undernutrition.

However, documentation of the beneficial effects of ASF consumption is insufficient to understand the role that livestock production can play in ameliorating undernutrition. Researchers, donors and policy makers can benefit from additional information on what practices, programmes or policies can influence ASF consumption (particularly by certain target groups), but also how livestock ownership affects patterns of expenditures or labor allocation, and the synergies between livestock and crop production. The knowledge available about these relationships between livestock production and nutritional status is much more limited, but this information is essential if the potential nutritional benefits of livestock production are to be realized (and negative nutritional effects mitigated).

With the foregoing in mind, this document has the objectives of summarizing the existing literature on:

- The broader economic implications of the global undernutrition problem and the importance of addressing micronutrient deficiencies early in life to support human capital formation (Chapter 2);
- The nutritional impact of animal-source foods (Chapter 3);
- The relationships between livestock production and nutritional status related to food consumption (Chapter 4), including a conceptual framework identifying the complex dynamic linkages;
- The relationships between livestock production and nutritional status related to disease transmission and environmental toxins (Chapter 5);

The document concludes (Chapter 6) with recommendations for future research priorities and suggested research designs to adequately address them.

Before reviewing the literature specific to livestock and their products, it is useful to note that two recent discussions in the literature have generated evidence and lessons relevant to understanding the links between livestock keeping and human nutritional status. The first has been the discussion of "food-based" strategies to ameliorate undernutrition. Second, a series of studies in the 1980s and 1990s examined the general issue of how agricultural commercialization in developing countries affects nutritional status. These two discussions provide context regarding the role of livestock and animal source foods, and so are briefly reviewed here.

Animal Production as a Food-Based Strategy

A number of different approaches can combat (micro)nutrient deficiencies. Food-based strategies—also referred to as dietary diversification/modification strategies—include a wide range of activities. They aim to increase the production and availability of and access to foods rich in (a) specific nutrient(s), increase the consumption of these foods and improve the bioavailability of these nutrients in the diet (Ruel, 2001).

Advantages of Food-Based Approaches

A potential advantage of a food based strategy is that it is a more sustainable strategy than supplementation or fortification. Food based approaches are said to be sustainable because they allow people to take responsibility for the quality of their diet by growing their own nutrient-rich foods and making informed consumption decisions. As micronutrient deficiencies are often multiple in nature, an additional advantage is that several micronutrient deficiencies can be alleviated simultaneously without the risk of antagonistic interactions or nutrient overload (Gibson and Ferguson, 1998; Ruel, 2001).

Obstacles to Food-Based Strategies

Promoting food-based strategies faces challenges from both the supply and demand perspectives. On the demand side, the price of foods rich in micronutrients may be prohibitively high for many people in developing countries. It is not clear to what extent poor households could afford the addition of higher quality foods, such as small amounts of ASF, to their diets. Second, cultural and religious norms may prohibit the use of certain foods; many such restrictions exist particularly for specific animal foods in the diet (Allen et al., 2001; Ruel, 2001). Third, even if nutrient-rich foods are available to the household, intra-household food allocation preferences in some regions may limit the consumption of these foods by women and children (Gittelsohn and Vastine, 2003).

Improving the supply of selected foods may be difficult in areas where no tradition exists of their production. In the case of livestock keeping, the cost of animal acquisition and the risk of animal loss due to disease or theft may form important obstacles to poor families. In a study in Bolivia, India and Kenya, an open-ended ranking of livestock problems was conducted. Access to fodder and water, livestock diseases and theft were identified as important problems (Heffernan et al, date unknown).

Importance of Education and Social Marketing to Change Behavior

A good understanding of local dietary patterns, food beliefs, preferences and taboos is essential for the successful implementation of food based strategies. Furthermore, knowledge about the ability to change attitudes and practices is required (Gibson and Ferguson, 1998). The inclusion of education and social marketing to bring about behavioral change has been integrated in many more recent food based interventions aimed at improving vitamin A nutrition. These efforts often had a clear positive impact on both knowledge and behavior (Ruel, 2001).

Lessons from the Cash Crop Literature

The information provided in this review also can be viewed as a specific case of what are sometimes termed the “agricultural determinants of nutrition.” There are many similarities between the focus of the current review on the links between livestock production and nutritional well-being and the focus of a series of case studies conducted in the 1980s examining the impact of a shift from subsistence crop to cash crop production in smallholder farming households. These studies are summarized in von Braun and Kennedy (1994a), and were also concerned with understanding the pathways by which changes in own food production might affect household nutritional well-being, either directly through availability, diversity, and allocation of own-produced foods, or indirectly through largely income-mediated effects on food consumption and health.

Although the specific empirical findings regarding these dynamics varied across the case studies depending on contextual factors, the overall conclusion was that even major changes in household agricultural activities as households increased their market orientation generally translated into only very modest—but typically positive—changes in household nutritional well-being, at least in the short term (von Braun and Kennedy, 1994b). The income-mediated pathway was recognized as being much more important than the direct effects of consuming own-produced foods, in part because there was little effort devoted to nutritional education or other behavioural changes that could enhance direct effects. The studies also highlighted two reasons why the impact of changes in agricultural activities on nutritional well-being was so modest. First, the income-mediated pathway involves a series of linkages, and as the impact of an increase in income is transmitted through these linkages, the impact quickly becomes diluted. This effect was demonstrated by Bouis and Haddad (1990) in terms of a declining cumulative elasticity for nutritional status with respect to a change in income, based on data from the Philippines (Table 1 summarizes linkages for the weight-for-height indicator; the cumulative effects for other indicators may be larger). Secondly, no evidence was found that increased income led to reduced morbidity among children in the households, again, at least in the short term, and so without a significant improvement in the health environment, the health interactions that influence nutritional well-being will dampen the impact on any improvements in food consumption. This finding highlights the important interactions and synergies between health and nutrition.

The foregoing discussion illustrates that the linkages between livestock production and nutritional outcomes can be viewed in a number of different ways. First, livestock production can be viewed as a food-based nutritional strategy, with the possible advantages of greater sustainability than supplementation approaches and the ability to address multiple micronutrient deficiencies simultaneously—but many of the likely limitations of food-based strategies will apply to livestock production. Second, livestock products can often be viewed as “cash crops” for which much of the production is sold rather than consumed directly by the households producing them. Thus, to understand the relationship between livestock production and human nutritional outcomes, it is necessary to consider not just the direct effects of livestock production consumption by the households, but the effects of income generated from animal product sales and the effects of allocating labour and other household resources to livestock production rather than other activities. The more general point is that consideration of the role that livestock play in what are sometimes termed “livelihood systems” is complex, dynamic and multi-faceted. As a result, a number of observers have concluded that integrative systems methods will be useful (Christopher Barrett and Alice Pell, personal communications, 2005). A systems approach is therefore used throughout this document to underscore these essential concepts.

Table 1. Response of Preschooler Weight-for-Height with Respect to a Change in Household Income

Elasticity of	With respect to	Elasticity of Individual Link	Cumulative Elasticity
Household food expenditures	Household income	0.65	…
Household calorie intake	Household food expenditures	0.17	0.11
Preschooler calorie intake	Household calorie intake	1.18	0.13
Preschooler weight-for-height z-score	Preschooler calorie intake	0.39	0.05

Source: Bouis and Haddad (1990), p. 117

Methods Employed in the Review

The information summarized in this report was developed based on searches of diverse bodies of literature. The evidence regarding the linkages between economic growth and nutrition is based on review papers by Demment and collaborators. The evidence reviewed in Chapter 3, 5 and 6 is based on recent review articles located using Medline. When recent review articles were not available, a broad range of the actual literature was reviewed and summarized. When possible, evidence relevant to developing countries was summarized. In some cases, however, only studies conducted in developed countries could be found.

Our discussion of the linkages between livestock production and nutritional status related to food consumption (Chapter 4) is based on two basic types of literature: studies examining the effects of specific livestock production interventions (e.g., projects to promote or improve livestock production) and studies not related to a specific programmatic or policy intervention, but with sufficient data to allow an analysis of the impacts of livestock production on nutrition-related indicators. None of the studies reviewed in Chapter 4 meets the criteria for controlled experimentation. However, as discussed in that Chapter, the challenges of controlled experimentation encompassing entire agricultural production systems are daunting, and sufficient information for policy and programme development purposes will likely need to be developed through both quantitative and qualitative analysis of the context and behavior of these systems, but without the benefit of controlled experimentation.

The summary of intervention studies reviewed in Chapter 4 is based on the peer-reviewed and the grey literature. A primary search was done on Medline, using the following keywords: (aquaculture or livestock) and (nutrition or nutritional or "child growth" or diet or dietary or anthropometry or anthropometric). Additional articles from the peer-reviewed literature and relevant studies from the grey literature were identified through two literature reviews (Berti et al., 2004; Ruel, 2001), the use of reference lists and citation reports from identified studies and discussions with colleagues. The primary focus was to identify studies with a nutrition component. Given the importance of maternal income and maternal time as determinants of child nutritional status, the search was expanded to studies with a focus on these outcomes as well. Even though the potential of animal source foods in alleviating undernutrition is widely recognized, we did not find any previous review articles on the impact of animal production interventions on nutritional status. One literature review on the potential of food-based strategies to alleviate vitamin A and iron nutrition (Ruel, 2001) and another review on the effectiveness of agriculture interventions in improving nutrition outcomes (Berti et al., 2004) only covered a small number of articles that are included in our review.

The summary of studies not based on a specific intervention draws on previous review work by Nicholson et al. (2003) and emphasizes the impacts of dairy cattle production and milk consumption as illustrative of other likely linkages. Because a key linkage between livestock production and nutritional status is the degree to which livestock products produced by the household are consumed by its members, a summary of what is known about the relationship between livestock production and consumption was developed based on reported information from intervention and non-intervention studies. The studies were selected because they provided sufficient consumption and production data to allow examination of these relationships. Because relatively few of the studies focused on determination of production and consumption effects, the impacts are summarized with “arc elasticity” estimates that provide only a rough indication of the likely effects.

The pathways examined in this document are summarized in Figure 1. The bold arrows indicated linkages for which literature was reviewed. Dashed lines indicate relevant linkages not reviewed. It is important to note that many potential linkages between livestock production and nutritional status are not included in the figure nor reviewed in this document. The conceptual framework in Chapter 4 addresses these linkages in greater detail, however. In addition, although Figure 1 appears to imply direct and linear relationships among the variables, the actual relationships should be recognized to be nonlinear and dynamic, part of a complex system that may be usefully understood using systems analysis approaches.

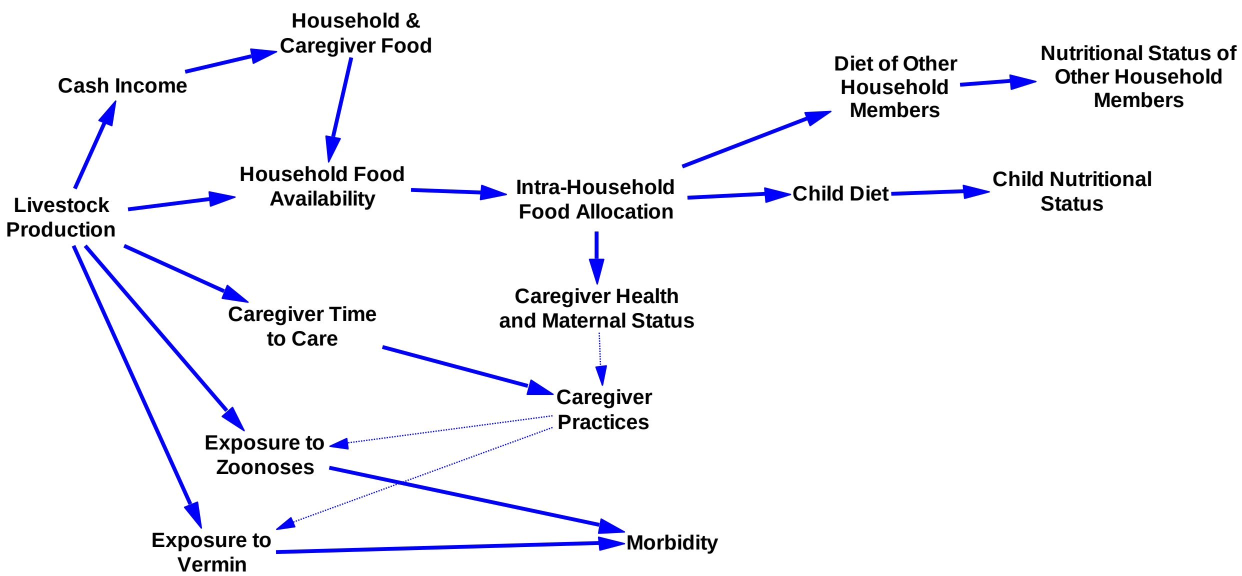

Figure 1. Pathways Between Livestock Production and Nutritional Outcomes Reviewed in this Document

CHAPTER 2: THE GLOBAL IMPLICATIONS OF UNDERNUTRITION

It is often suggested that to alleviate poverty in developing countries, economies must grow. However, without the necessary investments in human capital, national economic growth may not lead to poverty alleviation and socioeconomic development, nor be sustainable. Economic growth that leads to poverty alleviation must be fueled by the creative and physical capacities of people (Demment et al. 2003). The impact of undernutrition, especially micronutrient malnutrition, is established early in life (often *in utero*), leading to growth stunting, reduced cognitive abilities, lethargy and poor attention, and greater severity and rates of infection. These effects limit educational progress, physical work capacity, and life expectancy, thereby reducing individual lifetime productivity and the aggregate ability of the population to enhance its well-being and contribute to the building of strong economies. Combating malnutrition is not only an urgent humanitarian challenge, but is also imperative for economic development (Taniguchi and Wang, 2003). In failing to protect young children at the critical stages of their growth and development we risk compromising the ability of whole generations to not only survive but prosper, potentially resulting in failed economic development for decades to come (Grant, 1987). "In terms of a pro-poor, economic growth strategy that is sustainable, investment in nutrition is one of the best options" (Allen et al., 2001).

Although improving the welfare of human populations in developing countries has long been a goal of development efforts, two of the principal components of welfare--child development and nutritional status--rarely have emerged as explicit objectives. Martorell (1996) summarizes a conceptual model of development that links economic growth to poverty reduction, improved nutrition, and cognitive and physical development, which together generate increases in human capital (Figure 2). Increases in human capital then drive greater economic growth, which further fuels social sector investments in health, education, and nutrition. In such a dynamic system with important feedback mechanisms, the question for development agencies is where and how to intervene.

Development goals are usually narrowly defined in economic terms under the assumption that nutritional status is directly linked to income and that macroeconomic growth should have a positive nutritional effect at the household and individual level. This perspective essentially ignores the impact of nutritional status on national income. Hunt (2002) points out that the negative impacts of poor nutrition on national income are larger as a country's per capita income increases, because average labour productivity (and therefore wages) are larger.

One of the major constraints to the development of human capital and capacities is the impact of loss of human potential, both physical and mental, due to poor childhood nutrition. A substantial body of evidence now indicates that investments in nutrition programs are highly competitive with other development programs (World Bank, 1996). Some of the expected outcomes in terms of economic returns to nutritional improvements are the improved performance of workers, the protection of infants and children from cognitive impairment, reductions in infant and child mortality, and reductions in expenditures for primary health care (Berg, 1973). Adequate nutrition, especially during fetal and child development, is a fundamental component of human development, and therefore, national economic development.

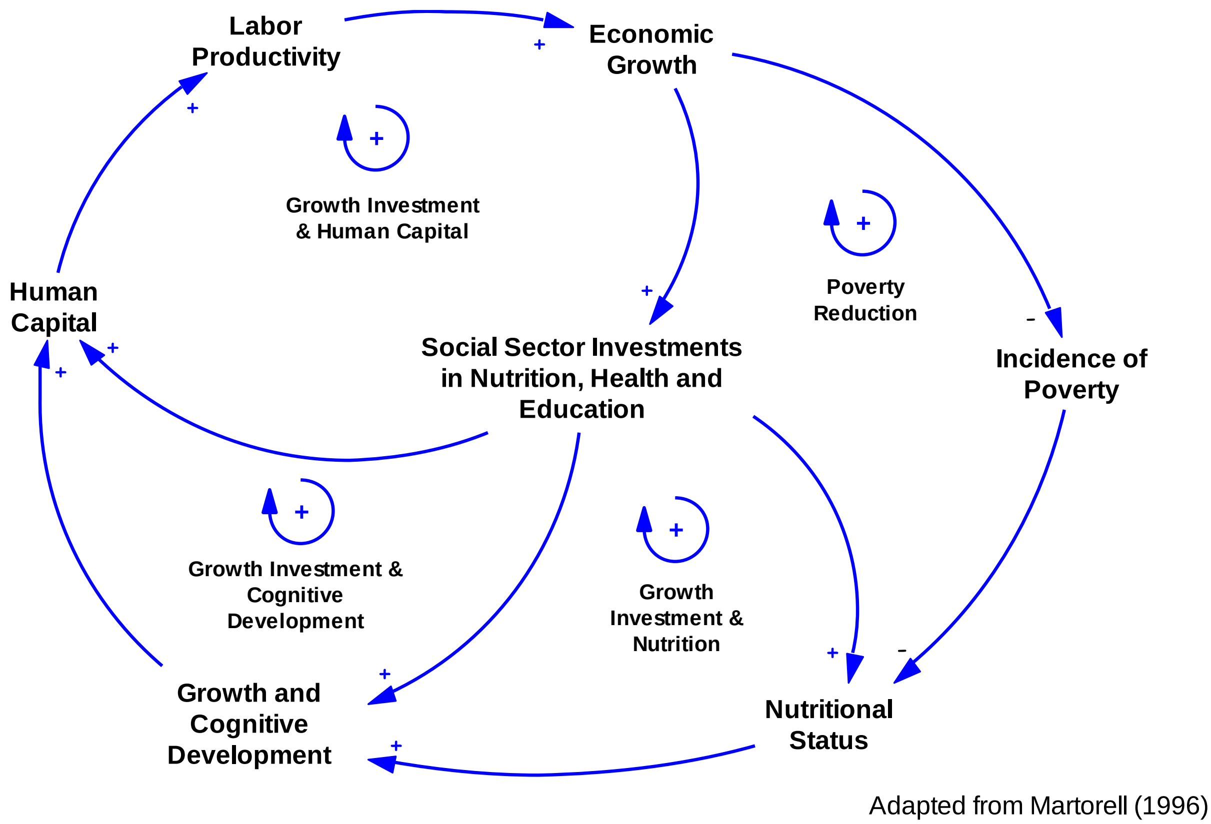

Figure 2. Dynamic Feedback Relationships between Nutrition and Economic Growth

Micronutrients: From Human to National Development

Widespread micronutrient malnutrition is well documented. Vitamin A deficiency, iodine deficiency disorders, and iron deficiency anemia are the most widely recognized, while the importance of zinc, vitamin B_{12}, folate, and several other micronutrients warrants additional attention (Ramakrishnan, 2002). Iron deficiency anemia is by far the greatest micronutrient problem affecting between 2-3.5 billion people globally (Ramakrishnan, 2002). In developing countries, 52% of pregnant women, 39% of children aged less than 4 years, and 48% of children aged five to 14 years are anemic (Bouis et al., 1999). Despite some success in some regions from iodized salt campaigns, one-third of the world's population is said to be at risk from goiter caused by iodine deficiency disorders (Ramakrishnan, 2002). Globally, 740 million people are affected with goiter (Ramakrishnan, 2002). Vitamin A deficiency is a major health problem in more than 60 countries. The WHO-MDIS system reported that in 1995, 29 million children aged less than 5 years had clinical vitamin A deficiency (WHO, 1995). Annually, between 250,000-500,000 pre-school children are estimated to go blind from this deficiency and about two-thirds of these children die within months of going blind (Bouis et al., 1999). FAO data suggest that more than half of the world's population is at risk of low zinc intakes (correcting for phytate inhibition) (Ramakrishnan, 2002). In Peru and Indonesia, studies have suggested that among pregnant and postpartum women, the prevalence of zinc deficiency was 60 and

24%,respectively (Ramakrishnan, 2002). The Child Nutrition Project of the GL-CRSP found that intakes of vitamin B_6 and vitamin B_{12} in young children and women of reproductive age in rural Kenya were below two-thirds of the Recommended Dietary Allowance (Siekmann et al., 2003).

Micronutrient malnutrition adversely affects all attributes of individuals that determine their productive capacity. Micronutrient malnutrition leads to low birth weight (Mackey, 2000), which has a negative effect on the trajectory of an individual's future lifetime productivity (Martorell, 1996) through its impact on life expectancy **(**Popkin and Lim-Yhanez, 1982**),** decreased work capacity (Haas et al., 1996), and higher rates of infection (Mackey, 2000; MacDonald et al., 2000). As reviewed by Black (2003), cognitive capacity is impaired by micronutrient malnutrition (Martorell, 1996; LaRue et al., 1997; Behrman, 1993). The impact of this loss on the educational achievement of children is augmented by lower attention span (Shariff et al., 2000), increased lethargy (Scrimshaw, 1989), and delayed enrollment in, and early drop-out from, school (Glewwe et al., 1999). "Education raises productivity in the market and in the household by enhancing information acquisition; it improves the ability to learn" (World Bank, 1995). If one accepts the development model that identifies the individual as the primary unit in development, then it is evident that micronutrient malnutrition has a pervasive limiting effect on the creative and physical capacity of individuals and constrains national development and economic growth.

Linking Nutrition, Education, Wealth and Economic Growth

Nutrition is related to educational performance in a number of ways. According to Galor and Mayer (2002) general health (and therefore nutrition as a major determinant of general health) affects the returns to education: 1) by enabling the formation of human capital in the early years and throughout youth, which increases the efficiency of education; 2) by raising skilled and unskilled labor efficiency; and 3) through promoting longevity, itself influenced by early (nutritional) health, by lengthening the time during which education will yield returns. Weak health and poor nutrition among school-age children diminish their cognitive development either through physiological changes or by reducing their ability to participate in learning experiences - or both (Glewwe et al., 1999; Del Rosso and Marek, 1996). Growth retardation is associated with a substantial reduction in mental capacity and adverse school performance, even in mild to moderate cases, and ultimately leads to reduced work productivity (MacDonald et al., 2000; Shariff et al., 2000).

There is a great deal of evidence supporting these conclusions. Findings from the INCAP study that followed individuals from childhood to adulthood indicate that nutritional interventions that improved growth rates in Guatemalan children also had important effects on height, fat-free mass, work capacity, and intellectual performance (Martorell et al., 1995). A study of over 3000 children in China found that children with lower height-for-age were consistently further behind in their expected school grade (Popkin and Lim-Yhanez, 1982). Results indicate that the process of stunting, which results from prolonged nutritional deficiencies, may have persistent effects on cognitive development, which consequently compromises children's learning capabilities in school (Galor and Mayer, 2002). Alba (1992) examined the effects of preschool health and cognitive ability on eventual educational attainment. His results indicate that both preschool health status and preschool cognitive ability simultaneously and independentl*y* exert significant positive influences on educational attainment. A difference of one standard deviation in the z-score of height-for-age, accounts for 1.9 to 2.6 more years of school attendance (a significant predictor of national economic growth, see below). According to human capital theory, Maglen (1990) maintains that there is a direct causal effect running from schooling to wages and this causality is due to increases in productivity that education confers on the more schooled workers. Galor and Mayer (2002) also conclude that in order to achieve the greatest human capital investments, policies promoting education must be carefully complemented with policies that promote the satisfaction of basic needs and health. Addressing micronutrient malnutrition is one very important component of such investments.

Available estimates of the impact of cognitive achievement on wage rates in developing countries for urban Kenya and Tanzania (Boissiere et al., 1985), for Ghana (Glewwe, 1991), and in rural Pakistan (Behrman, 1993) suggest that child nutrition/health and schooling act through cognitive achievement to significantly increase wages and economic productivity (Behrman, 1993; Sachs, 2001). Galor and Mayer (2002) show that when families cannot supply their basic needs (including but not limited to nutritional needs), their compromised health may give rise to a condition that does not disappear when funds are made available for education, but not for basic health needs. As a result, inadequate nutrition in children may lead to low levels of education and therefore to an intergenerational state of poverty.

Glewwe and Jacoby (1995) found that children in low-income countries often delay primary school enrollment as a rational response to early childhood malnutrition. The cost of the average delay is about 6% of an individual’s lifetime wealth. These results indicate that early childhood nutrition interventions can lead to substantial increases in lifetime wealth. Recent empirical findings confirm a positive relationship between wages and academic achievement, as measured by test scores in both developed (Murnane et al., 1995; Neal and Johnson, 1996) and developing countries (Boissiere et al., 1985). With the general tendency in many developing economies to move toward greater dependence on global markets, the economic impact of nutrition for poor people may increase with better incentives and rewards for greater productivity (Behrman, 1993). This point is particularly relevant to the information revolution where cognitive capacity is critical for technical adaptations and competition in global markets. Based on these findings, if malnutrition does compromise school performance and school performance is an important determinant of individual economic productivity, then economic growth and improved nutrition can be mutually reinforcing (Glewwe et al., 1999).

Investment in education leads to the accumulation of human capital, which is key to sustained economic growth and increasing incomes (World Bank, 1995). For example, the World Bank (World Bank, 1995) found that differences in the educational level of the labor force explain about 20% of the differences in growth across states in Brazil. Arcand (2001) shows that nutrition has substantial effects on economic growth both directly and indirectly through life expectancy and schooling. Barro (1996) concluded from his study of the health and human capital of 100 countries observed from 1960 to 1990, that years of schooling at the secondary and post-secondary levels for males aged 25 and over showed a significantly positive effect on economic growth. Studies from the World Bank in 1980 and 1981 claim that the average social real rate of return to primary schooling in low-income countries is 24% (Behrman, 1993). Their regression results show that the rate of return to schooling is about 5.9% for the population of young adults and adolescents in these studies.

Although the education systems of developing countries are often weak, they are one of the primary mechanisms available to nurture new ideas, build human capital, and promote national capacity in order to participate in an increasingly information-oriented world. Primary education alone is the single largest contributor to growth in both the cross-country and cross-regional comparisons and the within-country analyses carried out to explain the East Asian "miracle" of development (World Bank, 1995). A people-based development model integrates the physical and mental capacity of children with education to build national human capital. Because the education systems in developing countries are often lacking resources, the educational outcome for students should be very sensitive to the degree to which children are able to capture the full intellectual potential of their schooling.

Micronutrient Sufficiency and National Economic Development

Malnutrition affects national economic development in two ways (Khan, 1984). First, individual productivity is lost thereby directly reducing national productivity. Second, malnutrition places increased demands on social services and public revenues that indirectly absorb economic productivity. The estimates of the economic losses from malnutrition for human productivity are in the range of 10-15%, for gross domestic product (GDP) in the range of 5-10%, and losses in children's disability-adjusted life years (DALY) in the range of 20-25% (WHO, 2000). Economic productivity is compromised for those who need it most, the poor (WHO, 2000). The World Bank World Development Report 1993 estimates that deficiencies of vitamin A, iodine, and iron alone could lower gross domestic product (GDP) in developing countries as much as 5%, but addressing them comprehensively would cost less than one-third of a percent of GDP (Bouis et al., 1999). Horton and Ross (2003) suggest that even this World Bank estimate is probably understated; based upon their estimate, Bangladesh alone loses 2% of its GDP just to iron deficiency and that South Asia loses roughly $5 billion annually due to iron deficiency. One FAO study estimates aggregate economic growth shortfalls ranging from 0.16 to 4.0% suffered in sub-Saharan Africa. In that study and in contrast to the usual findings of the literature, the well-known Africa dummy effect actually becomes insignificant once health indicators and nutritional variables are both included (Arcand, 2001).

The link between health and micronutrient status and human capital has a major impact on national economic development. Fogel (2002) estimates that half the economic growth of the United Kingdom following the industrial revolution was due to the increased capacity of its people, and can be explained by nutrition’s impact on human health and life expectancy. If creativity and working capacity were the forces behind the industrial revolution, then cognitive and intellectual capacity, as well as overall individual economic productivity will also be critical to national development in the information revolution.

CHAPTER 3: THE NUTRITIONAL IMPORTANCE OF ANIMAL SOURCE FOODS

Food Consumption Patterns in Resource-Poor Households

Many people worldwide—and especially in low income countries—suffer from micronutrient deficiencies as a consequence of diets consisting of little more than staple foods such as rice or maize. Children and women of reproductive age have particularly high micronutrient requirements and are thus especially vulnerable (Neumann et al., 2003; Ruel, 2001). A number of factors contribute to the high prevalence of these deficiencies. People mainly consume plant based diets (Figure 3, Appendix Figure 1). These diets are not only often low in several micronutrients (Neumann et al., 2003), they are also important sources of two anti-nutrients: phytic acid and dietary fiber. These anti-nutrients both independently inhibit the absorption and/or retention of nutrients such as iron and zinc (Gibson, 1994b). The low intake of ASF in these populations further contributes to the low intake of bio-available micronutrients. The cost of meat, fish and milk sometimes makes them unaffordable for poor people (Smitasiri, 2000). Finally, in some settings intra-household food allocation patterns may limit the intake of animal source foods for the most vulnerable groups such as women and children (Gittelsohn and Vastine, 2003).

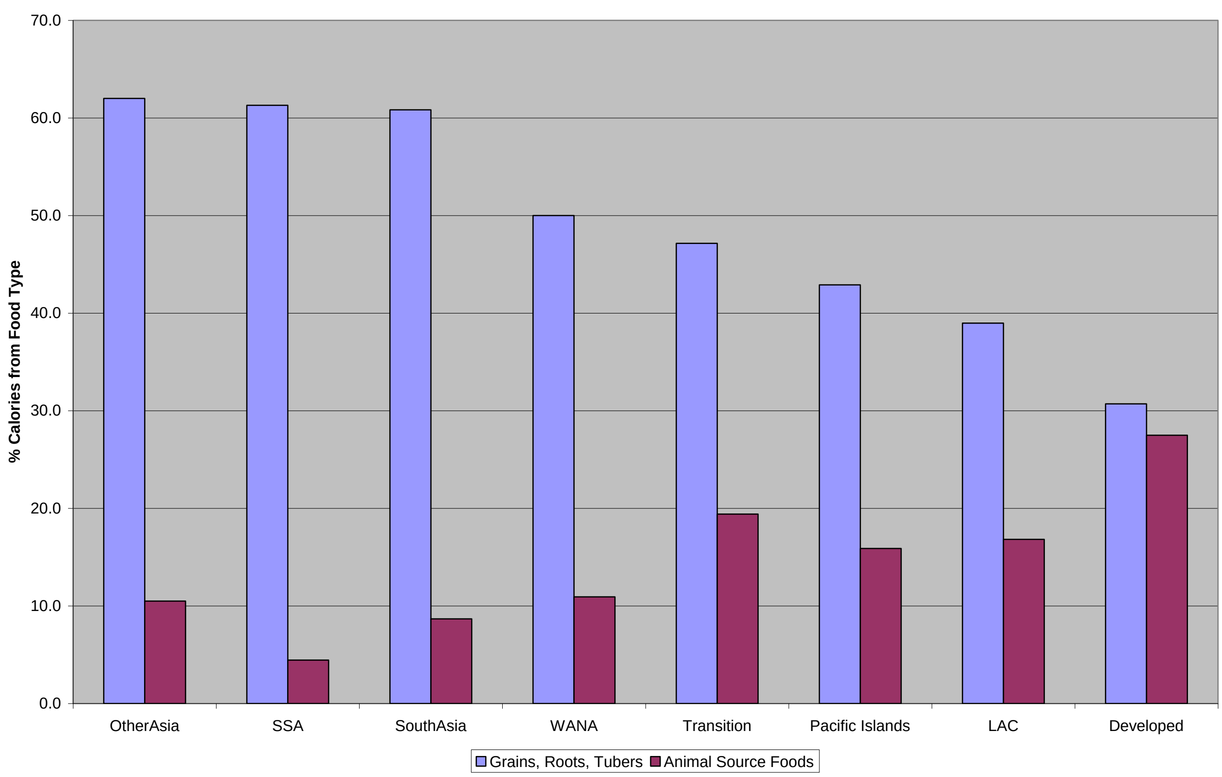

Figure 3.. Percentage of Calories from Grains, Roots, and Tubers and Animal Source Foods, by Region, 2000-2002 (Source: FAO)

Of particular concern is the dietary quality of complementary foods in developing countries. Complementary foods are the foods given to infants as a complement to breastmilk (or to formula) when breastmilk can no longer satisfy the nutrient requirements of the infant. In most developing countries (and in some groups in developed countries) the micronutrient density of traditional i.e. unfortified complementary foods is inadequate to meet infant requirements. It is particularly hard to meet the requirements for calcium, absorbable iron and zinc, vitamin A and sometimes riboflavin. Vitamin B_{12} is only found in breastmilk and animal products (Allen et al., 2001).

In summary, due to their low dietary quality, diets in developing countries are often deficient in a number of nutrients. The most widely recognized deficiencies in the developing world are vitamin A deficiency, iron deficiency and iodine deficiency disorders (Ramakrishnan, 2002). The deficiencies of other nutrients such as zinc, calcium, riboflavin, vitamin B_6 and B_{12} and folate constitute important problems as well (Murphy and Allen, 2003; Ramakrishnan, 2002). ASF can provide these nutrients, alleviating many of these deficiencies. These nutrients are discussed in the next section.

Nutritional Characteristics of Animal Source Foods

Key nutrients

ASF are dense sources of bioavailable energy, protein, and micronutrients. Many minerals and vitamins are better absorbed from ASF than they are from plant source foods. ASF also tend to be rich in fat, making them more energy dense and a good source of fat soluble vitamins (Allen et al., 2001). As a consequence, relatively small amounts of animal source foods can contribute substantially to dietary adequacy. The following paragraphs provide an overview of the key nutrients in ASF, describing the foods that contain these nutrients, the deficiency disorders associated with each nutrient and the prevalence of those deficiencies. A summary is provided in Table 2. Information on the nutrient composition of a large number of ASF consumed in Kenya and Indonesia is provided in Appendix B.

Protein

Animal products are an excellent source of high-quality and readily digested protein. Animal proteins contain a full complement of essential amino acids and their amino acid composition most resembles that of the human body. Animal proteins are therefore considered the highest quality available (Neumann et al., 2002). Although protein is an essential nutrient, protein-energy malnutrition (PEM) is more often caused by deficient dietary intake than by deficient protein intake. As a general rule, if commonly consumed cereal-based diets meet energy needs, they tend to meet protein needs as well, particularly when the diet is complemented with modest amounts of legumes and vegetables (Latham, 1997). One example is provided by the work of the Nutrition Collaborative Research Support Program (NCRSP), conducted in the 1980's in marginally malnourished areas of Kenya, Mexico and Egypt. The protein intake was found to be adequate for all children, even though the diets in Kenya and Mexico were low in animal

Table 2. Summary of Nutrients and Relationships with Animal Source Foods

	Nutrient (an X indicates that the ASF contains the indicated nutrient)						
Animal Source Food	**Protein**	**Vitamin A**	**Iron**	**Zinc**	**Calcium**	**Riboflavin**	**Vitamin B12**
ASF generally	**X**	**X**					
Beef			**X**	**X**		**X**	**X**
Poultry			**X**	**X**		**X**	**X**
Pork			**X**	**X**		**X**	**X**
Fish			**X**	**X**	**X**[2]	**X**	**X**
Eggs			**X**	**X**[1]		**X**	**X**
Dairy Products			**X**	**X**[1]	**X**	**X**	**X**
Comments on ASF	Animal proteins of highest quality	ASF contain retinol or retinol esters	Meats contain heme iron, which is better absorbed and facilitates non-heme iron absorption	ASF zinc highly bioavailable	Dairy products major source of dietary calcium	Milk and dairy products, organ meats, and eggs are good sources	ASF are only source except some algae
Effects of deficiency	Protein deficiency not normally a cause of growth faltering	Growth faltering, impaired vision and immune response, maternal mortality	Impaired growth, cognitive development and immune function in children; lower work capacity in adults	Pregnancy complications, low birth weight, impaired immune function, growth faltering, maternal and infant mortality	Nutritional rickets, possible hypertension benefits	Stunted growth, skin lesions and other problems	Megaloblastic anemia, demyelinating disorder
Affected groups	Those with deficient dietary intake	140 million preschool children, 7 million pregnant women	Estimated 4-5 billion people	Estimated half of world population has inadequate intake	Problem is reappearing, but estimates not available	Good estimates unavailable, but may be large incidence	High prevalence in many countries
Interactions			Absorption depends on iron stores and dietary factors	Protein increases zinc absoption, calcium (dairy) may inhibit			

1 Indicates concentrations lower than in flesh meats.
2 When consumed with bones.

products (Murphy and Allen, 2003). Current evidence suggests that normally protein deficiency is not a cause of growth-faltering in developing countries. This assertion is based on the fact that in a variety of populations with stunted children, dietary protein and amino acid intakes seem to be adequate. This implies that promotion of ASF consumption to address protein deficiencies is unwarranted in many cases. However, this may not be true in areas where complementary foods are based entirely on staples low in protein, such as sweet potato and cassava (Brown et al, 1998).

Vitamin A

Vitamin A can be obtained from plant sources (mainly fruits and vegetables) in the form of provitamin A carotenoids, and from animal sources in the form of retinol or retinol esters. De Pee's work in Indonesia showed that the bioavailability of carotenoids (i.e. vitamin A precursors from plant sources) is significantly lower than previously assumed (de Pee et al., 1998). As a consequence, the potential of plant sources to improve or maintain vitamin A status is being questioned by nutrition practitioners (Ruel, 2001)[1]. Vitamin A deficiency can lead to growth faltering and impaired development, vision and immune system. Extreme deficiency leads to blindness and death (Ruel, 2001). Vitamin A deficiency has further been associated with maternal mortality (West, 2004). An estimated 140 million preschool children and seven million pregnant women suffer from vitamin A deficiency (United Nations System Standing Committee on Nutrition, 2004).

Iron

Dietary iron can be classified as either heme (iron from flesh foods such as meat, fish and poultry) and non-heme iron (iron in dairy products, eggs and plant foods such as beans, cereals, nuts, fruits and vegetables). The absorption rate of heme iron is high (15 to 35%), while the absorption of non-heme iron is lower (2 to 20%) (Monsen, 1988). Nutrient interactions affecting iron absorption are discussed below. Iron deficiency is one of the most prevalent nutrient deficiencies and is estimated to affect four to five billion people. In young children, iron deficiency may impair growth, cognitive development and immune function. In school-aged children, it can affect school performance, and in adults it may lower work capacity. Iron deficiency anemia is responsible for tens of thousands of maternal deaths each year (Ruel, 2001; United Nations System Standing Committee on Nutrition, 2004) .

Zinc

Zinc is found in both plant and animal sources, but the highest concentrations are found in ASF, particularly in organs and the flesh of beef, pork, poultry, fish and shellfish. Amounts in eggs and dairy products are lower. Nuts, seeds, legumes and whole grain cereals contain relatively high

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[1] Although this is generally true, bioefficacy probably varies greatly among plant sources. The overall carotenoid bioefficacy of a mixed plant-food diet is now believed to be lower than previously thought, but the bioefficacy of mango or orange-fleshed sweet potato may be much higher than the average for a plant-food diet. Thus, specific interventions promoting these foods may improve vitamin A status under certain conditions.

amounts of zinc, but also phytates that limit their absoption. Lower zinc levels are found in tubers, refined cereals, fruits and vegetables (Hotz and Brown, 2004). Zinc in animal source foods is highly bioavailable. During digestion of these foods certain L-amino acids and cysteine containing peptides are released, forming soluble ligands with zinc. In developing countries, the most important sources of zinc are often cereals and starchy roots and tubers. These plant based diets are often high in phytic acid and dietary fibre, two factors known to inhibit the absorption of Zn (Gibson, 1994a). Severe zinc deficiency is rare, but even mild zinc deficiency may have far reaching consequences. Zinc deficiency may result in pregnancy complications, low birth weight, impaired immune function, maternal and infant mortality and morbidity and growth faltering in infancy and childhood (Gibson, 1994a). It is estimated that nearly half of the world population is at risk for inadequate zinc intake, with estimates as high as 95% for South Asia and 70% for Southeast Asia, North and Sub-Saharan Africa and the East Mediterranean (Brown et al., 2001).

Calcium

The major source of dietary calcium in many parts of the world is dairy products. Another good source of calcium is fish if consumed with the bones (Roos et al., 2003). Certain green vegetables (including turnip greens, Chinese cabbage, mustard greens, kale and broccoli) are relatively rich sources of calcium as well (Wood, 2000). The calcium content of fruits and grains are in general rather low (Weaver, 2001). The levels of dietary fiber, phytate and oxalate influence calcium absorption (Wood, 2000). Nutritional rickets can be caused by calcium deficiency, vitamin D deficiency or a combination of both factors (Pettifor, 2004). There is some evidence that calcium supplementation in calcium deficient women and women at high risk of hypertension reduces the risk of hypertension and hence mortality risk (Villar et al., 2003). We could not find estimates of the global prevalence of rickets, but the problem is clearly reappearing (Wharton and Bishop, 2003).

Riboflavin

Milk and dairy products, meats (especially organ meats) and eggs, and green vegetables such as broccoli and spinach are good sources of riboflavin. Cereals are rather poor sources, but enriched flour and breakfast cereals contribute significant amounts of riboflavin (McCormick, 2000). Significant amounts of riboflavin may be lost due to light exposure, for instance during the storage of milk in clear containers. It is likely that large amounts are lost as well during the sun-drying of fruits and vegetables (Rivlin, 2001). Inadequate dietary intake of riboflavin leads to stunted growth and 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). Riboflavin deficiency in developing countries may be quite prevalent, as a consequence of diets low in ASF and vegetables. Good global prevalence data are not available. An estimated 90% of all adults in China are riboflavin deficient (Allen et al., 2001).

Vitamin B12

Except for some algae (such as seaweed), animal products are the only source of vitamin B_{12} (Shane, 2000). A diet low in ASF therefore constitutes a risk for vitamin B_{12} deficiency. Severe vitamin B_{12} (and folic acid) deficiencies can cause megaloblastic anemia. Vitamin B_{12} deficiency further leads to a demyelinating disorder of the central nervous system, often accompanied by painful paresthesia (i.e. a burning or prickling sensation) of the extremities (Stabler, 2001). The prevalence of vitamin B_{12} deficiency is very high in many countries, including Kenya, India, Guatemala and Mexico (Murphy and Allen, 2003). Reliable data are not available on global prevalence of vitamin B_{12} deficiency (Allen et al., 2001).

Nutrient Interactions

Both meat and dairy products have been shown to affect the absorption of dietary iron and zinc. The enhancing effect of meat on non-heme iron absorption is well established. Animal protein may enhance zinc absorption as well. The inhibiting effects of dairy products and calcium on iron and zinc absorption are less clear. Animal products tend to be rich in fat and can thus enhance the absorption of fat soluble vitamins. More details about these nutrient interactions are provided in the following paragraphs.

Meat and the Absorption of Iron and Zinc

Iron. The absorption of dietary iron depends on the level of iron stores and a number of dietary components consumed concomitantly. Diets in developing countries are often rich in phytates and dietary fiber, both known to be strong inhibitors of non-heme iron absorption[2]. Meat, fish and poultry are effective dietary enhancers of non-heme iron absorption. Consequently, adding meat or fish to a meal is advantageous not only because it adds more absorbable iron, but also because it increases the absorption of non-heme iron (Monsen, 1988). Quantitatively, the addition of relatively small amounts of meat, fish or poultry can easily double the iron absorption from a meal. The addition of fish (or an amount of synthetic amino acids equivalent to 100 g of fish) doubled iron absorption from black beans. Similarly, 80 g of ground beef added to a meal consisting of a bun, french fries and a milk shake doubled iron absorption. Quantitatively, 1.5 g of meat is believed to be equivalent to 1 mg of ascorbic acid in its effect on iron absorption. The association between the enhancing effect of ascorbic acid and that of meat, fish or poultry depends, however, on the inhibitory ligands in the meal (Allen and Ahluwalia, 1997).

Zinc. The amount of protein in a meal increases zinc absorption. As protein is a major source of zinc, increased dietary protein will lead to increased zinc intake and a higher bioavailability of the zinc provided. The type of protein also affects bioavailability. Animal protein has been found to counteract the inhibitory effect of phytate on zinc. This may, however, be a consequence of amino acids keeping the zinc in solution rather than a unique animal protein effect (Lonnerdal, 2000).

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[2] Ascorbic acid (vitamin C), another plant source nutrient, is an effective enhancer of non-heme iron as well (Allen and Ahluwalia, 1997).

Dairy and the Absorption of Iron and Zinc

Iron. The effect of dairy products on iron nutrition has been studied extensively, producing conflicting results. The factors in milk that may limit iron absorption are protein (in particular casein), phosphate and calcium (Jackson and Lee, 1992). Calcium is believed to be the most important inhibitor (Lynch, 2000). In a review of the effect of dairy foods on iron availability, Jackson and Lee concluded that on the whole, dairy foods had little effect on iron availability when they were part of a complex meal. Iron enhancers may override any inhibitory effects of dairy foods (Jackson and Lee, 1992). A review of experimental and epidemiological studies on the impact of calcium intake on dietary Fe bioavailability concluded that the effect of increasing the calcium content of Western diets is unlikely to have a biologically significant effect on Fe status in most individuals (Lynch, 2000).

There are two main qualifications for the interpretation of the above results. First, the focus of both reviews cited above is on studies conducted in well-nourished populations. It thus remains unclear how dairy products may affect iron nutrition in populations with inadequate intakes of bioavailable iron. Secondly, an alternative explanation for an inverse association between the consumption of dairy products and iron status is that dairy may displace iron-rich or iron-enhancing foods in the diet. The inverse association between iron status and milk consumption shown in 1.5 to 4.5 year old children in Great Britain was not found in children consuming moderate to high amounts of meat (Thane et al., 2000). Finally, the potential inhibitory effect of dairy on iron absorption does not hold for human milk. Iron from breastmilk is highly bioavailable (Fomon, 1993).

Zinc. Calcium *per se* is unlikely to affect zinc absorption (Lonnerdal, 2000). The well-documented inhibitory effect of phytate on zinc, however, is believed to be aggravated by dietary calcium. A zinc-calcium-phytate complex is formed in the intestinal lumen in the presence of high amounts of calcium. This complex is less soluble than the zinc-phytate complexes and hence leads to a further reduction in the bioavailability of zinc (Gibson, 1994b). More recently, however, this theory has been questioned (Lonnerdal, 2000).

Fat and the Absorption of Fat Soluble Vitamins

The absorption of β-carotene, retinol and other fat soluble vitamins can be impaired in diets low in fat (de Pee et al., 1995). Animal products tend to be rich in fat and can thus enhance the absorption of these vitamins (Brown et al., 1998). Note, however, that fat from plant sources enhances the absorption of these vitamins as well.

Nutritional Benefits of Animal Source Foods Throughout Life

Good nutrition is important throughout life. During pregnancy and lactation, nutrients needed for fetal growth and milk production increase women’s total requirements. Pregnancy may deplete maternal nutrient stores, contributing to poor child nutrition beginning *in utero*.. During infancy and early childhood, recurring infections and inadequate dietary intakes particularly of energy, protein, vitamin A, zinc, calcium and iron further contribute to poor growth and micronutrient undernutrition. Underweight children have more severe illnesses and a significantly higher mortality risk. Undernutrition in school-age children adversely affects school attendance, performance and learning. As the probability for significant catch-up growth is limited, a stunted girl is very likely to become a stunted adolescent and later a stunted woman. This directly affects her health and productivity, but adult stunting and underweight also increase the odds of having low birthweight children. In this way, a cycle of undernutrition is created (WHO, 1998; United Nations and IFPRI, 2000).

Thus, undernutrition during infancy and early childhood has profound negative short-term, long-term and intergenerational effects. Short-term effects include lower physical growth and more frequent infections. Undernutrition has long-term effects on cognitive development, school performance and achievement (Glewwe et al., 1999; Del Rosso and Marek, 1996). Finally, undernutrition early in life has negative effects on the health of the next generation as stunted girls are more likely to have a low birth infant (Neumann et al., 2002; United Nations and IFPRI, 2000). A comprehensive assessment of nutritional deficiency disorders and their consequences and the potential preventive role of ASF is beyond the scope of this review. In the following paragraphs we provide a general overview of the possible contribution of ASF to improving nutrition and well being throughout the life cycle. We focus on salient nutrition related conditions.

Pregnancy

Maternal nutritional status before and during pregnancy determines both her own health and the health of the fetus and infant. With respect to maternal health, deficiencies of iron, zinc, vitamin A and calcium have been associated with pregnancy complications. Anemic pregnant women have a significantly greater risk of death in the neonatal period. Vitamin A deficiency significantly increases maternal mortality as well. Zinc deficiency is associated with preterm delivery and pregnancy induced hypertension. Calcium supplementation in calcium deficient women and women at high risk of hypertension may reduce the risk of hypertension and hence mortality risk (Hotz and Brown, 2004; Villar et al., 2003; Viteri, 1994; West, 2004).

Short stature, low pre-pregnant weight and low weight gain are important determinants of intra uterine growth retardation (Norton, 1994). Maternal intake of animal source foods during pregnancy was positively associated with infant growth beginning *in utero* in the NCRSP (Neumann et al., 2002). Maternal hemoglobin concentration is strongly associated with infant birth weight and preterm birth. Iron supplementation, however, has not been found to increase birth weight or the duration of gestation (Rasmussen, 2001). In a number of random, placebo controlled zinc supplementation trials, maternal zinc deficiency has been associated with low birth weight, intrauterine growth retardation, poor fetal neurobehavioral development and increased neonatal morbidity. The findings, however, were inconsistent across studies (Hotz and Brown, 2004). The effect of maternal vitamin A deficiency on the health of the newborn is not clear (Christian, 2003).

The consequences of intra uterine growth retardation (IUGR) are grim. IUGR children have increased risk of neonatal death, and suffer significantly more from diarrhea and pneumonia. Long term consequences include reduced body size, changes in body composition and lower muscle strength. There is growing evidence that IUGR is associated with high blood pressure, non-insulin-dependent diabetes, coronary heart disease and cancer in adult life (United Nations System Standing Committee on Nutrition, 2004).

Infancy and Childhood

Animal source foods play an important role in micronutrient nutrition especially for children because they are a rich, dense and highly bioavailable source of critical nutrients such as zinc, iron, Vitamin A and B_{12}. Whereas most growth failure occurs between six and 24 mo of age, early damage due to anemia and chronic malnutrition may only partially be reversed in later life (MacDonald et al., 2000). A child who is stunted at five years of age is likely to remain stunted throughout life (Allen et al., 2001).

Breastfeeding

Maternal micronutrient deficiencies are more likely than protein and energy deficiency to have an affect on the composition of breastmilk. Maternal riboflavin, vitamin B12 and vitamin A deficiency have been shown to result in lower concentrations of these nutrients in breastmilk and to consequently cause adverse outcomes in the infant. On the other hand, breastmilk concentrations of calcium, iron or zinc are relatively unaffected by maternal calcium, iron or zinc intake or status (Allen, 1994).

Complementary Feeding

The main problem with complementary foods in developing countries is that they have a low energy and nutrient density. Only animal products are sufficiently dense in iron, zinc, calcium and riboflavin to provide the daily requirements of these nutrients in complementary foods. Between the age of six and 12 months for instance, only liver can be consumed in amounts large enough to meet the iron requirements (Brown et al., 1998). An estimated 587,000 child lives could be saved annually if children were to be fed adequate complementary foods (Jones et al, 2003).

Child Growth

Animal products are a particularly good source of six nutrients of concern to child growth: calcium, iron, zinc, vitamin A, riboflavin and vitamin B_{12} (Murphy and Allen, 2003). Numerous studies have been conducted on the association between child growth and both milk and meat. The main findings are summarized below.

Milk. A positive association between milk consumption and child growth has been shown in both observational and controlled intervention studies. In five Latin American countries, milk intake was found to be associated with height-for-age Z-scores of children 12-36 months old, after controlling for a number of possible confounders (Ruel, 2003). Milk intake was also positively associated with linear growth in a group of healthy 2.5 year old Danish children (Hoppe et al., 2004). Kassouf (1991) found that children consuming milk had higher mean height-for-age status than children not consuming any milk among a sample from rural and urban Brazil.

In a large-scale controlled intervention trial, milk consumption resulted in improved growth (Haskell and Brown, unpublished review, as cited by Allen, et al., 2001). In a recent controlled feeding trial in Kenya conducted by the Global Livestock CRSP, Grillenberger *et al.* studied the differential effects of three equally caloric school snacks, providing 20% of the children’s energy requirement. One snack consisted of a vegetable stew plus oil, the two others of the same stew plus milk or meat. A fourth group served as control. The median age at enrollment was 7.1 years, and children were supplemented when schools were in session for a period of two years. They found no overall effect on linear growth in schoolchildren. Only children with height-for-age Z-scores below -1.4 benefited from the milk supplement and gained more height than the children in the other supplementation groups. The authors suggested that the lack of an overall effect might be a consequence of the initial poor micronutrient status of the children (Grillenberger et al., 2003). Furthermore, one would expect the potential to benefit at this age to be limited.

Meat. A positive association between the consumption of animal protein from meat and fish and growth of undernourished children has been shown in a number of observational studies. The NCRSP studies showed a strong positive association between ASF (including meat and dairy) and physical growth (Neumann et al., 2002). Marquis *et al.* found that ASF improved linear growth of Peruvian toddlers consuming marginal diets. The most commonly consumed animal foods were red meat and chicken (Marquis et al., 1997). A study in 2.5 year old (well-nourished) Danish children, however, failed to find an effect of meat intake on linear growth (Hoppe et al., 2004).

We only found one intervention study on the association between meat and child growth. Grillenberger *et al.*'s study in Kenya found that children receiving meat had a significantly greater mid-upper-arm muscle area than those in the milk, energy and control groups. There was no effect of meat on linear growth, a possible consequence of the initial low micronutrient status of the children (Grillenberger et al., 2003). As stated earlier, the age of the children may have limited their potential to respond to the intervention in linear measures but not in muscle mass.

It is worth referring to a number of studies conducted in Dutch children fed macrobiotic diets. These almost vegan diets consist of grain cereals, vegetables, pulses and sea vegetables, with small amounts of cooked fruits and occasionally fish. The children were found to have stunted growth after the first 6 to 18 months of life (Dagnelie and van Staveren, 1994). Children growing up in families that increased the consumption of fatty fish, dairy products or both after the baseline study, grew more rapidly than the other children (Dagnelie et al., 1994).

Child Morbidity and Mortality

Undernutrition (including micronutrient undernutrition) is an important cause of child mortality through the higher case fatality rates of infectious diseases in malnourished children. According to Pelletier el al. **(**Popkin and Lim-Yhanez, 1982), 56% of childhood deaths in developing countries can be attributed to malnutrition and its synergistic effects on infectious disease. MacDonald et al. (2000) estimate that approximately 55% of under-five mortality in developing countries is associated with malnutrition. Jones *et al.* estimated that alleviating zinc and vitamin A deficiency could prevent nearly 700,000 child deaths annually (Jones et al., 2003).Inadequate nutrition may also play a role in increasing the virulence of infections (MacDonald et al., 2000). Some studies have shown that micronutrient deficiencies compromise immune response to HIV, increase the rate of progression to AIDS, and increase maternal-infant transmission (Mackey, 2000). Micronutrient deficiencies may play important roles in causing and facilitating some cancers in that they cause DNA damage in the form of chromosome breaks or DNA oxidation (Ames, 2001).

Early Cognitive and Behavioral Development

Nutrition early in life largely determines the cognitive potential through which education builds functional capacity. A considerable body of evidence indicates the strong link between micronutrient malnutrition and cognitive development (Black, 2003), thereby indicating potentially negative implications for the educational achievement of affected children. In the Dutch study, macrobiotic infants had slower gross motor and language development than infants in the omnivorous control group (Dagnelie et al., 1989). There is a substantial body of observational studies showing a significant association between iron deficiency and children's cognition and behavior. The results from supplementation trials are far less convincing, especially in children younger than two years old (Grantham-McGregor and Ani, 2001). There is growing evidence that zinc deficiency contributes to compromised neuro-behavioral function in infants and children (Hotz and Brown, 2004). As mentioned earlier, vitamin B_{12} deficiency has been associated with low cognitive and psychomotor development (Neumann et al, 2002).

School-Age Cognitive Development and Learning

Observational studies by the NCRSP in the 1980s indicated that the only dietary measure that predicted cognitive performance in children in three developing countries was the amount of ASF in the diet (Allen, 1993). Only one controlled feeding trial has studied the impact of ASF on child cognitive development. The earlier cited GL-CRSP intervention in Kenya, providing three groups of children with a different school snack, two of which contained either milk or meat, investigated cognitive outcomes as well. Cognitive assessments included the Raven's Colored Progressive Matrices, the Verbal Meaning test and an Arithmetic test. On the first test, children in the meat group significantly outperformed children in all other groups. There were no demonstrable differences in performance on the Verbal Meaning test, but in the Arithmetic test, children in the meat and energy only group performed better than children in the control group. Children in the energy only group performed significantly better than children in the milk group. The authors suggest that meat provides the micronutrients that are deficient in the children or provides them in more bioavailable form than in the other supplements (Whaley et al., 2003). The authors, however, fail to explain why on the Arithmetic test, children in the energy group significantly outperformed children in the milk group.

Adolescence

During adolescence, linear growth accelerates as a result of hormonal changes. Undernourished girls tend to grow slower and longer than better nourished girls. As a consequence, undernourished girls may not finish growing before their first pregnancy. Adolescent girls who are still growing tend to give birth to smaller babies. Since calcium is needed for bone growth of both the adolescent and the fetus, calcium status is of particular concern (United Nations and IFPRI, 2000).

Adulthood

Adult Work and Caregiving Capacity

The link between (adult) undernutrition and decreased work capacity is well established. Inadequate energy intake and Fe deficiency anemia both impair physical activity patterns, which leads to decreased productivity (Collins and Roberts, 1988). Haas postulated that caregiver iron deficiency and anemia could have a direct impact on the quality of childcare through reduced work capacity. The amount of time available for childcare could also be negatively affected, because more time is needed to perform work related activities as a consequence of reduced physical fitness (Haas and Brownlie, 2001).

Old Age

Recent studies have shown that malnutrition is common in the elderly in developing countries. Nutritional status is related to functional ability, psychomotor speed and coordination and the ability to independently carry out activities of daily living. Little is known, however, about how the nutritional status of older people can be improved and whether this would lead to improved functional ability (United Nations and IFPRI, 2000).

Animal Source Foods and Chronic Disease Risk

ASF tend to be rich in energy, saturated fat and cholesterol, all of which have been associated with increased risk of chronic disease. In a careful review of the literature, Hu and Willet (1998) found that red meat (such as beef and pork) and white meat (such as fish and chicken) can have opposing health effects. Red meat consumption probably increases the risk of coronary heart disease and several forms of cancer. Moderate intakes, however, may decrease the risk of hemorrhagic stroke, where initial levels of red meat intake are low. Poultry consumption does not seem to be a risk factor for chronic disease, whereas fish may lower the risk of coronary heart disease.

The authors further emphasized the need to distinguish eggs and dairy from meats. The consumption of eggs (up to one egg/day) has not been associated with adverse effects on chronic disease. Higher consumption of dairy fat is likely to increase the risk of coronary heart disease due to increased cholesterol levels. Dairy consumption may further increase the risk of prostate cancer. There is also evidence, however, that moderate dairy consumption may be protective (Hu and Willett, 1998).

Note that evidence used by the authors was largely based on studies in well-nourished groups. As a consequence, it is difficult to assess the effects of increases in ASF consumption in populations with very low initial intakes. Furthermore, little is known about the trade-off between the health benefits of animal products as a rich source of micronutrients and the risk of chronic disease. In two recent studies, Biesalski, 2002 and Hill, 2002) pointed out that in healthy diets, the beneficial role of meat outweighs the uncertain association with cancer.

HIV/AIDS, ASF Consumption and Livestock Keeping

Although it is distinct from the role of ASF and chronic disease risk, the relationship between HIV/AIDS, ASF consumption and livestock ownership merits a brief discussion here. This discussion is necessarily more speculative than those preceding it, in part because it discusses the potential role that livestock may play in addressing some of the social implications of the HIV/AIDS crisis.

HIV infection can lead to micronutrient deficiencies and depletion of lean body mass as a consequence of decreased food intake, mal-absorption and increased utilization and secretion of nutrients. Lower plasma levels of vitamin A, vitamin E and vitamin B_{12} have been found to be associated with faster disease progression. Low plasma selenium has been associated with higher mortality in the US and Tanzania. In the majority of studies the onset of clinical disease and the rapid decline of those patients were linked to a greater micronutrient deficit than their healthier counterparts (Patrick, 2000). These deficiencies cause problems such as diarrhea neuropathy, skin conditions, lactic acidosis, increased transmission rates of the HIV-1 as well as decreasing patient CD 4 blood counts, a measure of increasing disease (Dreyfuss et al., 2002).

In studies of energy and protein levels in the diet of infected adults, levels were found to be 26% lower than the recommended daily allowance for a healthy adult, leading to premature muscle wasting and progression of disease (Luder, 1995). This becomes even more of a concern as protein requirements may be as much as doubled for an HIV positive individual (Haddad and Gillespie, 2001). Note that low plasma levels of vitamin A, zinc and selenium can be a consequence of the HIV infection and do not necessarily indicate poor nutritional status. Also, studies on the association between zinc status and HIV-outcome produce conflicting results. In general however, evidence from several well conducted observational studies and randomized trials indicate that multivitamin supplementation reduces clinical HIV disease progression (Fawzi et al., 2005).

In pregnant women, multivitamin supplements (including vitamin B, C and E) reduced adverse pregnancy outcomes. The same supplements during lactation decreased child morbidity and mortality. In pregnant women, vitamin A has been associated with increased mother-to-child transmission (Fawzi et al., 2005).

The nutritional resources of ASF contain essential micronutrients, protein and energy necessary for HIV positive and AIDS patients. Despite the assumed benefit of an ASF-based diet, few have studied the impact of this type of diet on HIV/AIDS patients. One South African study with asymptomatic HIV positive adults concluded that a diet rich in ASF and vegetables, in contrast to a high carbohydrate diet, protected the patients from liver damage, variations in blood parameters such as anemia, blood lipids and proteins, and better stabilized the patient condition (Vorster, 2004). Other studies on diet and HIV from the United States concluded that balanced diets of essential micronutrients in conjunction with anti-retroviral therapy are the best ways to protect patients from the progression of HIV (Kruzich et al., 2004; Luder et al., 1995). These studies show promise of using diet to slow the progression of disease, but more research is necessary to understand the benefit of ASF and its role in HIV/AIDS.

In addition to the dietary aspects of ASF, livestock is critical in the family unit of HIV households. Livestock keeping is replacing more advanced cropping and skilled labor in affected families as labor capital and technical knowledge is lost with debilitation and death of primary laborers. The assets that livestock provide can utilize child labor to provide for treatment costs and expenses associated with infected households. (Haddad and Gillespie, 2001).

CHAPTER 4: IMPACTS OF ANIMAL PRODUCTION ON NUTRITIONAL STATUS

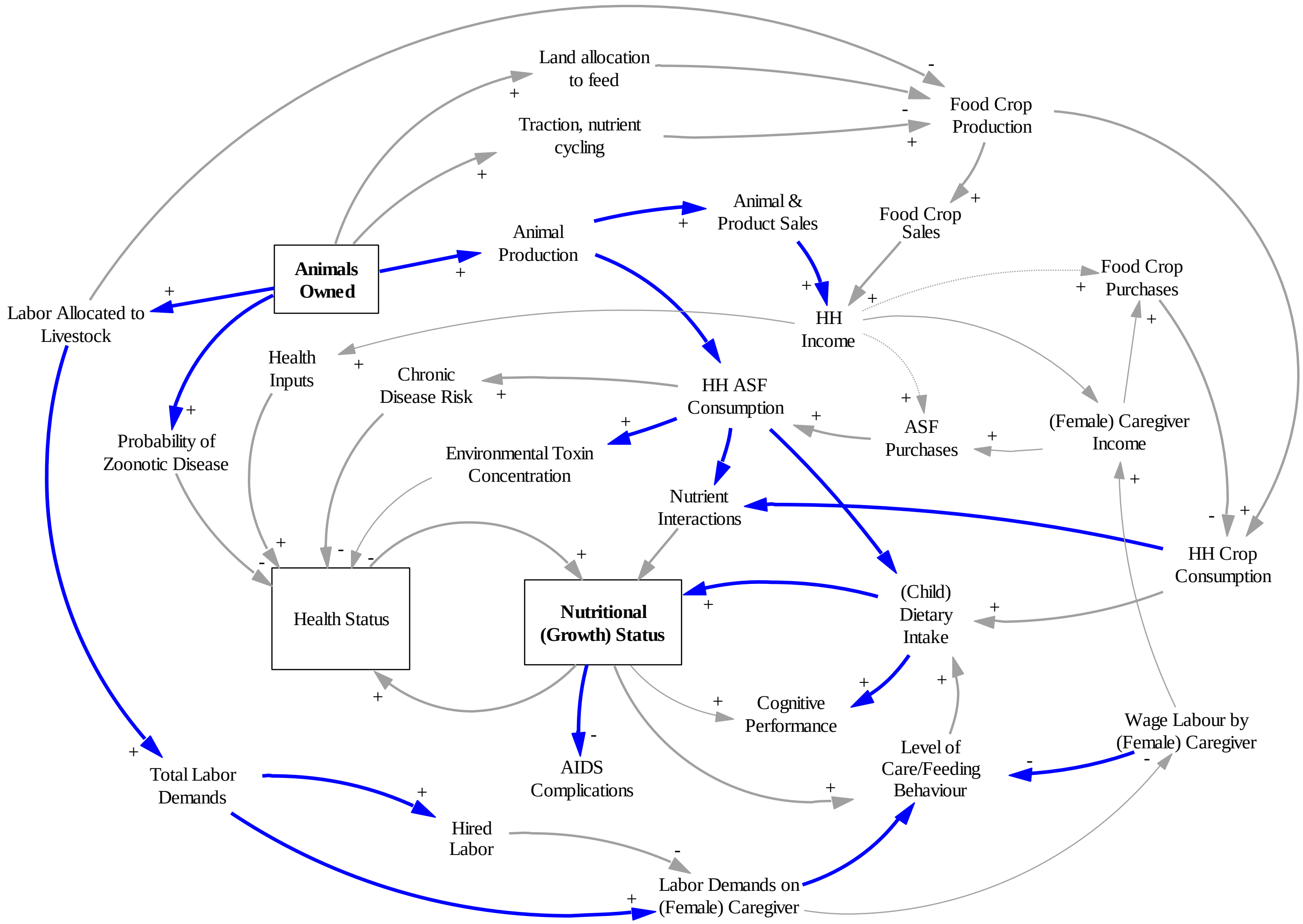
Conceptual Framework

Numerous conceptual frameworks have been developed to examine the causes and consequences of undernutrition (e.g., UNICEF, 1990; von Braun et al., 1994; Grosse, 1998b). The conceptual framework developed herein emphasizes the main pathways by which livestock production (including fisheries) may influence child nutritional status, and therefore omits or diminishes the importance of some factors described in previous frameworks. However, our framework explicitly acknowledges that the linkages between livestock production and nutritional status form a complex nonlinear dynamic system. In this system, the presence of multiple pathways and feedback loops (Sterman, 2000) has important implications for the dynamics of household welfare, including child nutrition.

To capture this complexity, Figure 4 expands on the basic relationships presented in Figure 1. . Although this diagram is visually complicated, it is important to note that the actual linkages between livestock production and nutritional outcomes are yet still more complicated, and that effective interventions to improve nutritional status in this system necessitate an understanding of how all of the relevant elements of the system interact. Child nutritional status is depicted as intertwined with child health status. This is represented as two state variables (shown as boxes in Figure 4), each that positively influences the other[3]. Child nutritional status is determined by the intake of nutrients by the child, as well as the current health status, because the presence of infection can influence intake, absorption, use and requirements of nutrients by the child (Latham, 1997). The three conditions necessary to support child growth include adequate household nutrient availability (household consumption of ASF and staple crops from own production or purchases), the level of child care and feeding behaviour (Engle et al., 1999), and health inputs sufficient to maintain child health status. Adequate nutritional status (often measured by attained growth) has positive effects on other indicators, such as cognitive performance. In cases where nutritional status is not adequate, other health issues (including complications from HIV/AIDS) will also be present. As noted in the previous chapter, interactions among the components of the diet consumed also influence the nutritional status. Although not shown for simplicity, nutrient availability for the other members of the household can have indirect impacts on child nutritional status, because the nutritional status of adults can influence food availability through food crop production, wage labor (and therefore household cash income) and the amount and quality of care and feeding behavior.

[3] Some authors have argued that the more general term "health status" should be used rather than separating health and nutritional status. However, the distinction between the two can be helpful to represent how infection interacts with malnutrition. Note that the formulation in the figure for the relationship between child nutritional status and health status is general and allows non-linear and non-additive (synergistic) effects.

Figure 4. Graphical Representation of Hypothesized Relationships Between Livestock Production and Nutritional Status



Arrows between variables indicate hypothesized causal relationships. The + or - signs indicate hypothesized direction of effects.

The impacts of animal ownership on child nutritional status can result from a number of different pathways, some of which are indicated with bold arrows in Figure 4. One pathway involves the competition between resources allocated to livestock production versus food crops. Ownership of livestock (or an increase in their number) can result in an increase in the land and other resources devoted to feed crops[4], which, other things being equal, would reduce household food crop production. However, livestock may also contribute to more rapid and efficient nutrient cycling, which could increase soil nutrient content, yields, thereby having a positive impact on food crop production (Delve et al., 2001). Moreover, a larger number of animals owned implies increased ASF production (of meat, milk and eggs), which can result in an increase in both nutrient availability when these ASF are consumed by the household, and household income (if the animals, ASF and(or) products (e.g., manure, skins) are sold.

The impact of an increase in household income from livestock production can be a crucial link in understanding the impacts on child nutrition. If additional income is spent on ASF and food crop purchases, this increases household nutrient availability and dietary intake, assuming that the household does not simply use higher incomes to purchase more expensive calories, protein, or micronutrients (Senauer, 1990; Kennedy, 1994). Additional income spent on health-related inputs can complement the impacts of increased food expenditures. The propensity of the household to spend additional income on food and health-related items is often associated with gender patterns of income control (Thomas, 1997; Tangka et al., 2000). If livestock production reduces household income controlled by caregivers (usually women, who tend to have higher propensities to spend additional income on food and health), then the nutritional impacts may be muted or negative. However, if additional income is used for food purchases, nutritional impacts will be more positive. Although not shown, household income may also be invested in other productive assets, and this may increase non-agricultural income and household income over time. This suggests the potential for positive longer-term impacts if some of that additional income is used to increase household nutrient availability.

Another potential pathway for negative impacts of livestock production is through labour allocation (von Braun et al., 1994). Livestock may increase total labor demands on the household, including the caregiver for the children (or the children themselves in some cases). This has the potential to negatively affect the level of care and feeding provided by the caregiver (Huffman, 1987), in part through additional energy and protein demands worsening the nutritional status of the care giver. If the household makes use of hired labor to provide the additional labor necessary to care for livestock, impacts on the children and caregiver may be limited.

Other pathways involve health effects not always directly related to undernutrition *per se*. Excessive consumption of ASF can result in an increased risk of chronic disease (e.g., heart disease). In addition, the presence of livestock increases the probability that children and other household members contract animal-borne diarrheal diseases (Grosse, 1998a) and other zoonotic

[4] In most cases, livestock use land resources of marginal suitability for crop production or require little if any land (confined larger stock, or smaller stock such as poultry), but sometimes there may be direct competition, such as improving feed in livestock development projects. The National Dairy Development Project operating in Kenya in the 1980s and 1990s actively promoted a cut-and-carry forage system using improved grass species, which in the absence of specialized forage producers or underutilized land would imply competition with land devoted to other crops.

diseases (such as tuberculosis), which would negatively influence both health and nutritional status. The environmental toxins that are sometimes concentrated in ASF may also have negative health impacts (These linkages are discussed in detail in the following chapter).

Thus, the ownership of livestock can have both positive and negative impacts on child nutritional status, depending on which pathways dominate. This conceptual framework suggests that the ultimate outcome is an empirical rather than theoretical question. It also indicates that the impacts of livestock production on child nutrition overlap to a large extent with a number of larger development themes: technology adoption, commercialization of semi-subsistence agricultural production, and intra-household (gendered) distribution of work, income, and food.

Causality and Observational Studies

Before discussing the evidence from the literature concerning the linkages between livestock production and nutrition, it is relevant to discuss the different standards used by various disciplines to define knowledge. More specifically, individuals from different disciplines often are not in agreement about what constitutes sufficient evidence of 'causality' for a given intervention or effect, and this is the case for the evidence relating animal ownership to nutritional outcomes. It is also often the case that individuals from different disciplines are not entirely familiar with the perspective of individuals from other disciplines with regard to the types of evidence that are considered adequate or 'convincing.' Because this document was developed by a multi-disciplinary team of researchers (primarily nutritionists and agricultural economists), it is relevant to make the underlying assumptions and definitions explicit, and to justify the inclusion in this review of studies using a variety of methods to assess the relationship between livestock ownership (and sometimes production, e.g., for fish) and nutritional outcomes.

First, it is appropriate, although challenging, to attempt to define what is meant by 'causality.' Meadows and Robinson (1985) define causality to imply that a direct relationship between two variables is 'necessarily sequential in time and incorporates some hypothesis about the mechanisms whereby one element directly influences another" (page 11). This is largely consistent with the definition in Hoagland et al. (1982), which emphasizes that causality implies "responsiveness" (change in one variable leads to a corresponding change in another variable), "consistency" (the same responsiveness is observed across a variety of settings), "mechanism" (a hypothesized underlying process by which one variable results in a change in the other variable), and a way of showing that a change in one variable cannot cause a change in another (the "necessarily sequential" criterion is consistent with this)[5].

Given these definitions, what are the research methods that allow a researcher to infer causality in the relationship between two (or more) variables? There are many alternative perspectives on this issue, but we will focus on two of them here. For many scientists, the only method that can produce unambiguous results with respect to causality is controlled experimentation. Under certain conditions (random assignment of subjects to treatments and control groups, appropriate stratification, sufficient sample sizes and control of other factors that may influence the outcomes of the experiment), controlled experiments provide the strongest evidence of causal relationships

[5] Note that this concept can usefully be applied to individual causal links in a chain, but if there are feedback processes relating two variables, this criterion—as opposed to the sequential in time criterion—will not be appropriate.

(Hoagland et al., 1982). Of course, the inferences from controlled experiments may be weakened if the experimental controls are not adequate, there may be ethical issues with the random assignment of individuals to treatment or control groups, and in some cases random assignment may not be possible for a variety of reasons (including high costs and administrative complexity). However, for many disciplines this is the ‘gold standard’ for the evaluation of causality (Habicht et al., 1999).

Other disciplines, notably economics, often take a quite different view of causality. According to Ethridge (1995):

> Experimental methods…do not have the capability to establish causation…Evidence of causation is derived by first developing hypotheses of direction of causation from conceptual reasoning (theory), then examining for evidence of the expected relationship. If the empirical evidence exists to support the relationship, then it supports the hypothesis of causation. The causative implications come from the conceptual reasoning (theory) rather than the empirical evidence.

Ethridge’s essential points are not only that controlled experimentation *per se* is insufficient to determine causality, but that other research methods allow causal inference. Specifically, economists will often ascribe causality to results from econometric models formulated consistent with economic theory and the probable underlying data-generating process. This interpretation probably has its roots in the cost and difficulty in conducting economic experiments, at least for many relevant economic research questions.

These contrasting definitions of causality imply that results derived from different research methods are likely to have different interpretations and value for researchers from different disciplines. One categorization that helps to reconcile these differing points of view is described in Habicht et al. (1995). They argue that impact can be evaluated through assessments of “adequacy”, “plausibility” and “probability,” depending on the degree to which the decision maker needs to be confident that any observed effects are due to a particular programme or intervention. Under this categorization, plausibility assessments “go beyond adequacy assessments by trying to rule out…‘confounding factors’…that may have caused the observed effects.” Addressing these confounding factors can be done using a variety of methods, including “matching, stratification, or other forms of multivariate analysis.” They note that “plausibility assessments encompass a continuum ranging from weak to strong statements;” stronger statements are those that undertake a variety of analyses to exclude other possible explanations. Probability assessment (i.e., use of randomized assignment to treatment and control groups) ensures that the probability of confounding is measurable, but does not eliminate all confounding. The point of view is Habicht et al. is useful because it avoids all-or-nothing statements about the usefulness of information generated by various research methods. It therefore encourages the inclusion of a wider range of information—as relevant to a specific decision—and draws attention to the need for *assessment of the strength of the inferences* about the relationships of interest that can be drawn from a given—inevitably imperfect—study.

A discussion of the relationship between research methods and causal inferences is important for the identification of those methods that can be most usefully applied to analyze the linkages between livestock ownership and nutritional outcomes. As Habicht et al. note, “there are a number of reasons why probability evaluations are often not feasible," and "this approach is seldom mandatory or even feasible for the routine evaluation of programmes." A key challenge for many situations is obtaining adequate randomization of assignment to treatment and control groups for administrative, political, or ethical reasons. More specifically, Ruel (2001) notes that "random selection of participants is seldom feasible for large-scale, food based strategies…because households cannot be forced to engage in the activities being promoted." This limitation will nearly always apply when examining the effect of livestock ownership and(or) livestock-related development interventions on nutritional outcomes. In addition, even when adequate randomization is possible, it may be the case that the ability to extrapolate the results to other populations or geographic locations is limited.

In this review, we have somewhat arbitrarily divided our discussion of previous studies into two categories: studies based on livestock-related interventions and studies of livestock impacts not related to specific interventions. In general, the former are studies of interventions where households participated in a specific development project. None of these intervention studies fully meets the criteria for "controlled experimentation," because households were not randomly assigned to treatments, and in general there were few assessments of confounding factors. By the categorization of basic study types[6] presented in Hoagland et al. (1982), all of these studies reviewed herein would be characterized as "comparative observational studies."[7] Under their definition, a comparative observational study involves "systematic or planned collection of data over several persons, institutions or groups, using common definitions of background groups and outcome variables," but without random assignment of study units to treatments. Designs for comparative observational studies differ based on the number of treatment groups (one or more) and when data are collected (after treatment only or before and after). . . The reviewed studies not related to interventions typically rely on statistical analysis of cross-sectional data, with varying degrees of attention paid to the assessment of confounding factors, simultaneity bias, and other issues with the data-generating process. As a result, the degree of certainty in the outcomes from previous research on livestock-nutrition linkages is not as high as would be desirable for some scientists and policy decisions. However, in the spirit of Habicht et al., the information herein is likely to provide sufficient evidence for certain types of decision makers—and provide insights about how stronger empirical evidence can be generated.

Review of Intervention-related Studies

Studies with direct measurements of the impact of the promotion of ASF production on nutritional status are rare. Furthermore, most of the studies identified for this review suffer from important limitations in their design, evaluation and analysis, a problem previously identified in Ruel's review of food-based interventions for the control of vitamin A and iron deficiencies (Ruel, 2001). She categorized the main limitations in three categories:

1) Lack of replicated units of intervention and analysis;

2) Inappropriate selection of a control or comparison group;

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[6] Hoagland et al. indicate that most studies can be characterized as "experiments" or "observational studies." For each basic type of study, there are many specific data collection or analytical methods that may be appropriate.
[7] Rather than as poorly designed or implemented (controlled) "intervention trials".

3) Inappropriate control for confounding factors and intermediary outcomes.

Building on Ruel's format (Ruel, 2001), the design, intervention and evaluation characteristics and findings are summarized for each study (Table 2). Concerns with respect to the design and analysis are indicated in the second column. The specific limitations of each study are not repeated in the text below, but are taken into account when drawing conclusions in each section. In the next sections, we discuss the impact of the promotion of animal production on five different outcomes: production, income and expenditure, dietary intake and nutritional status, caregiver time and workload and caregiver income. These findings are summarized in the last five columns of the table.

Overview of the Reviewed Intervention Studies

The intervention-related studies reviewed include four on aquaculture, five on dairy production, three on poultry, and three in which livestock production was part of broader integrated projects with nutrition education components. The first four studies are evaluations of aquaculture interventions in Bangladesh. The primary objective of the interventions reviewed in Bouis et al. (1998) was income generation through polyculture fish production in household-owned or group managed ponds or through vegetable production. The intervention was mainly targeted to poor women and entailed credit and agricultural extension. Some nutrition education was provided, but improving nutrition was not the main goal of the intervention. Roos et al. (2003) studied an intervention in which poor farmers were trained in carp culture in small homestead ponds. Ponds were stocked with carp and either mola (a fish species rich in vitamin A) or other small indigenous fish species. The third aquaculture intervention in Bangladesh provided training and expected households to adapt one of three interventions: monoculture of tilapia or silver barb or polyculture of a mix of native and exotic carp species (Thompson et al, 2000). Finally, Brugere et al. (2001) conducted a qualitative study on the gender effects of cage aquaculture. The studied intervention promoted the development of aquaculture using small-scale low input cage systems and was targeted at the rural resource poor.

Five studies evaluated the impacts of four dairy interventions. The Karnataka dairy development program in India integrated rural households into the market economy by increasing the use of purchased inputs and increasing the marketed surplus through setting up dairy cooperatives in the villages. The Karnataka project was modeled after the larger and more well-known Operation Flood dairy development project (Alderman, 1987). Begum (1994) studied the Dairy Development Project in Bangalore (India) but does not provide any details on the nature of the intervention. Children in households belonging to the families who joined the dairy cooperatives were compared to children in other families. The first objective of a dairy intervention in Ethiopia was to enable resource-poor smallholder mixed-crop and livestock farmers to participate in market-oriented dairying. Secondly, the intervention sought to test the use of crossbred dairy cows for traction in addition to milk production. With the crossbred cows, the project introduced complementary dairy technologies. Farmers with crossbred cows were encouraged to grow fodder and received training on improved hygiene and restricted grazing. The project further provided veterinary and breeding services. Ahmed et al. (2000) studied the consumption and income aspects of this intervention, Tangka et al. (1999) the gender effects The last dairy intervention is the Kenyan National Dairy Development Project. Intensive dairy technology was promoted through the introduction of crossbred cows and fodder production (Mullins et al, 1996).

The next three studies evaluate poultry interventions in Egypt and Bangladesh. Galal et al. (1987) report on a small-scale agricultural intervention in two villages in Egypt. The project implemented 31 agricultural interventions, covering most of the crops produced in both villages. Poultry production was promoted as well. Almost half of the poultry farmers were women. Nielsen et al. (2003) studied the impact of the Participatory Livestock Development Project in Bangladesh. This project promoted semi-scavenging poultry production by rural poor women in small-scale enterprises. Loans and technical assistance were provided through women's groups. The goals of a separate project-- theBangladesh Smallholder Livestock Development Project-- were to increase per capita income and to increase animal protein consumption among rural poor. The project included the establishment of village organizations, awareness education, technical training and credit programs. All program beneficiaries were women (Nielsen, 1996).

Three interventions combined the promotion of different forms of food production with nutrition education. The Dairy Goat Development Project in Ethiopia was targeted at women who first organized themselves into small self-help, savings and credit groups and who were offered training in better dairy goat husbandry. Having demonstrated improved ability, women received local goats and then cross-bred goats. Since this project had no demonstrable impact on health and nutritional status, the project was expanded to interventions to improve vitamin A intake, including health and nutrition education, training in gardening and food preparation and the distribution of vegetable seeds. (Ayalew et al., 1999; Habtemariam et al., 2003). English et al. (1997) reported on an intervention in Vietnam that promoted the production of fish, eggs and livestock, as well as home gardening. Mothers of preschool children received nutrition education. The project in Thailand promoted the consumption of vitamin A rich foods (such as liver, eggs, green leafy vegetables) and the production of such foods (ivy gourd, poultry and rabbits). Social marketing techniques were used in the community based intervention provided by women leaders. The project further included a school-based nutrition program (nutrition education, improving the nutritional content of school lunches and activities such as poultry raising and fish ponds) targeted to 10- to 13-year-old schoolgirls. Finally, these girls received a weekly iron supplement of 60 mg ferrous sulfate (Smitasiri and Dhanamitta, 1999).

Impacts on Production

Eight of the 16 studies investigated the impact of the intervention on ASF production. Six of these studies found an increase in the production of the targeted ASF following the intervention (Alderman, 1987; English et al., 1997; Galal et al., 1987; Nielsen, 1996; Nielsen et al., 2003; Thompson et al., 2000). One of the poultry studies in Bangladesh found an increase in egg production, but no difference in the production of chickens (Nielsen et al., 2003). The aquaculture extension project in Bangladesh did not find a difference in fish production between ponds stocked with mola or other small indigenous fish species (Roos et al., 2003). Overall, the studies generally show an increase in the production of ASF following the wide range of interventions included in the review. The agreement between studies, despite their shortcomings, leads to the conclusion that ASF production can be successfully promoted.

Table 3. Summary of Intervention-Related Studies on Linkages Between Livestock Production and Nutritional Status

Country	Reference Concerns with Methods	Intervention	Evaluation		Findings				
			Design	Methods	Production	Dietary intake and nutritional status	Income and expenditure	Maternal income	Maternal time and workload
AQUACULTURE									
Bangladesh	Bouis et al. (1998) Non-random assignment of households to groups	Polyculture fish production in household-owned or group-managed ponds (or vegetable production) to improve income; some nutrition education was provided, but primary objective was not better nutrition	Three groups: a. Adopters b. Potential adopters (in non intervention villages) c. Random selection households not belonging to a. and b.	HH surveys	n.a.	No effect on fish consumption; shift to larger fish, i.e. effect on nutritional status may be negative Modest effect through increase in income Pre-schoolers are favored particularly boys Program effect on nutritional status not estimated	Positive but very modest increase in income	n.a.	Demands on time relatively small.
Bangladesh	Roos et al. (2003) Not clear how households selected Non-random assignment of households to groups	Poor farmers trained in carp culture. Household ponds were stocked with carp and either *mola* (species very rich in vitamin A) or other small indigenous fish species (SIS)	Treatment/control Post	HH surveys Fish consumption, production	No difference in production between *mola* and *SIS* ponds	No difference in fish intake between fish producing and non fish producing households 47% of the *mola* was consumed in the household, covering 21% of the recommended vitamin A intake	n.a.	n.a.	n.a.

Country	Reference Concerns with Methods	Intervention	Evaluation		Findings				
			Design	Methods	Production	Dietary intake and nutritional status	Income and expenditure	Maternal income	Maternal time and workload
Bangladesh	Thompson et al. (2001) Non-random assignment of households to groups	Aquaculture extension (pond aquaculture). Households expected to adapt monoculture of tilapia or silver barb or polyculture of native and exotic carp species using on farm resources.	Treatment/control Two control groups: neighboring households in same village and others from other area. Uses reported production and proportion consumed by households, but no statistical test	Household surveys Aquaculture inputs and outputs Fish consumption	Both extension recipients and neighbors have higher yields than control farmers	Intervention and neighboring households seemed to consume more fish	Return on investments higher in extension households	n.a.	n.a.
Bangladesh	Brugere et al., (2001) Very limited information about the village characteristics Non-random assignment of households to groups	Cage aquaculture development project in a non-Muslim dominated area in Bangladesh	3 households s in 3 villages (nine total): 2 villages where project had been implemented > 1 year (1 successful, 1 less successful village) 1 village where project had been implemented recently	Qualitative study	n.a.	n.a.	n.a.	Post-harvest decisions (eat or sell fish), and control over income earned, varied widely between regions	Women responsible for the most time and labor consuming tasks
DAIRY									
India	(Alderman, 1987) Non-random assignment of cooperative intervention to studied villages	Integrating rural households into a market economy by increasing the use of purchased inputs and increasing the marketed surplus Dairy cooperatives were set up in the villages	Treatment/control Pre/post (panel) comparisons of households in villages with and without dairy cooperatives	Household surveys Income and expenditure Production Food consumption	Villages with cooperatives produced twice the amount of milk as village in the control group as a consequence of the higher number of crossbred cows	Households in villages with cooperatives consumed *less* milk The nutrient consumption of milk producing households in intervention villages rose, that of none producing households fell	Income and expenditure increased	n.a.	n.a.

Country	Reference Concerns with Methods	Intervention	Evaluation		Findings				
			Design	Methods	Production	Dietary intake and nutritional status	Income and expenditure	Maternal income	Maternal time and workload
India	Begum, (1994) No details on intervention; Not clear how control group was selected (non-random assignment to groups); No statistical tests; No control for confounders	Dairy Development Project of the Indian government; formation of dairy cooperatives	Treatment/Control Post Three groups within treatment: large (LP, >5 l/day), medium (MP,2.5-5 l/day) and small producers (SP, <2.5 l/day))	24-hour recall in children 1 to 4 years	n.a.	Only children in the LP meet protein RDA LP children have the highest energy intake too (do not meet RDA) Overall, protein and energy requirements best met in LP and worst in NP.	n.a.	n.a.	n.a.

Country	Reference Concerns with Methods	Intervention	Evaluation		Findings				
			Design	Methods	Production	Dietary intake and nutritional status	Income and expenditure	Maternal income	Maternal time and workload
Ethiopia	Ahmed et al., (2000); Tangka et al., (1999) Self selection bias: Households' willingness and ability to pay costs of crossbred cows No before/after Not clear how evaluation households were selected Sampling flaws prevent attributing differences to program[1] Ahmed et al.: is "preliminary analysis", but follow up not found; Not clear what instruments were used to predict income Tangka et al.: adopters simply compared to non adopters No control for confounders Methodology not clear	Market oriented dairying for resource-poor smallholder mixed-crop and livestock farmers; use of crossbred dairy cows for milk production and traction; farmers with crossbred cows were encouraged to grow fodder and received training on improved hygiene and restricted grazing. The project further provided veterinary and breeding services.	Treatment/control Post	Household surveys Labor allocation Income Caloric intake	n.a.	Caloric intake 19% higher in participating households; Intake of fat, protein, retinol and iron also higher (Ahmed, Jabbar, and Ehui, 2000)	Income of treatment households 72% higher; Higher income associated with higher food and non-food expenditure (Ahmed, Jabbar, and Ehui, 2000)	Men's incomes benefited significantly more from intensified dairying than women's (Tangka, Ouma, and Staal, 1999)	No apparent increase in women's labor input (Tangka, Ouma, and Staal, 1999)

Country	Reference Concerns with Methods	Intervention	Evaluation		Findings				
			Design	Methods	Production	Dietary intake and nutritional status	Income and expenditure	Maternal income	Maternal time and workload
Kenya	Mullins et al. (1996) Small sample size Adopters simply compared with non-adopters (non-random assignment to groups) Before data collected through recall	National Dairy Development Project: intensive dairy technology through introduction of crossbred cows, fodder production	Before (recall) /after	Household survey	n.a.	Increased milk consumption	Increase in HH income Increases in food purchases, school fee payments and book purchases	Increase in maternal income	Higher workload for women
POULTRY									
Egypt	Galal et al. (1987) Baseline data collected but not used for impact evaluation No multivariate analyses or adequate control for differences between adopters and non-adopters No clear use of statistics	More and Better Food Project Combined activities promoting plant production with animal production (poultry). 47% of poultry farmers were women	Treatment/control (adopters compared to non-adopters)	Household survey? "homemaker's" Recall of foods eaten by all household members in last 24 hour s Very limited use of statistics	Increase in poultry production (and in maize, peanut and wheat production)	Iron, total protein and animal protein intake higher in adopting households Prevalence of iron-deficiency anemia dropped in school-aged children during the same time period	n.a.	n.a.	n.a.
Bangladesh	Nielsen et al. (2003) Not clear how households were selected for study (non-random assignment to groups) Small sample size	Participatory Livestock Development Project supporting semi-scavenging poultry production; loans and technical assistance are provided through women's groups.	Treatment/control After	Household survey 24-hour recall (women and girls), poultry production, socioeconomic status	Egg production significantly higher in adopting households No difference in chicken production	Egg and chicken consumption not different Women and girls in adopting households ate more fish	Egg and chicken sales significantly higher in adopting households	n.a.	n.a.

Country	Reference Concerns with Methods	Intervention	Evaluation		Findings				
			Design	Methods	Production	Dietary intake and nutritional status	Income and expenditure	Maternal income	Maternal time and workload
Bangladesh	(Nielsen, 1996) Methodology of data collection and analyses not clear Not clear whether increase in consumption comes from own production	Saving schemes, technical training for poultry rearing and credit programs; project beneficiaries were all women.	Before/after	Household survey	Chicken production increased	HH consumption of eggs, chicken, fish, meat and milk increased Frequency of vegetable consumption did not change Grain consumption increased	All reported improved economic conditions Both food and non-food expenditure increased; Percentage of income spent on food decreased	Women have gained influence in deciding on the use of income	n.a.
INTERVENTIONS INCLUDING NUTRITION EDUCATION									
Ethiopia	Ayalew et al. (1999) Habtemariam et al. (2003)[2] Baseline data could not be used, so only comparison participants/non-participants Control group self-selected, i.e. not necessarily "poorest of the poor"	Women focused goat development project without impact on nutrition was expanded to include to interventions to promote vitamin A intake, including nutrition and health education, training in gardening, food preparation and distribution of vegetable seeds; school garden clubs	Treatment/control Two treatment groups: local goats or cross-bred goats)	Households surveys Child (< 5 years) anthromopometry Clinical assessment of vitamin A deficiency	All of the newly started vegetable gardens during intervention period in participating households Participation significantly associated with vegetable garden ownership No other data on production	Goat owning households consume all produced milk 87% by adults as *hoja*[3]*;* children in participating households had slightly more diversified diet; more likely to consume milk >4x/week Participating households consumed egg yolk at low rate (.46 x/wk) but significantly more than controls (.29) No impact on child anthropometry; prevalence of clinical vitamin A defiicieincy lower in intervention children	n.a.	n.a.	n.a.

Country	Reference Concerns with Methods	Intervention	Evaluation		Findings				
			Design	Methods	Production	Dietary intake and nutritional status	Income and expenditure	Maternal income	Maternal time and workload
Vietnam	English et al. (1997)[4] Only 1 intervention and 1 control community; non-random assignment of treatments to communities	Fish ponds Livestock Home gardens Nutrition education	Treatment/control After	HH survey Maternal knowledge Morbidity Anthropometry Food intake	Larger production of fish, eggs, vegetables and fruits in treatment community	Children in treatment group had greater intakes of vegetables, fruits, energy, protein, vitamin A and iron, and better child growth		n.a.	n.a.
Thailand	(Smitasiri and Dhanamitta, 1999)	Promotion of poultry and rabbit raising and home gardens through a community based intervention; Nutrition education School-based nutrition program targeted to 10 to 13-year- old schoolgirls Girls received weekly iron supplement of 60mg ferrous sulfate School lunches were improved Activities such as poultry raising, fish ponds.	Before/after Treatment/control	HH survey 24-hour recall (in pregnant and lactating women, 10-13y old schoolgirls and young children) Biochemical assessment (in 10-13y old schoolgirls)	n.a.	Increased intake of vitamin A in both intervention and control groups, but greater in intervention group Inconsistent findings for iron intake No increases in fat intake Schoolgirls had improved serum retinol and serum ferritin	n.a.	n.a.	n.a.
Bangladesh, Nepal, Cambodia	HKI leaflet[5] Descriptive summary only	Integration of animal components into existing gardening activities: poultry and eggs in all countries, milk and fish in Bangladesh	Before/after (2 x-sectional surveys)	n.a.	n.a.	HH chicken liver consumption increased Proportion of liver from own prod. increased (Nepal, Cambodia) Increase in egg consumption (Bangladesh)	In Cambodja and Nepal: 31-65% of income from selling poultry used to purchase food	n.a.	n.a.

Country	Reference Concerns with Methods	Intervention	Evaluation		Findings				
			Design	Methods	Production	Dietary intake and nutritional status	Income and expenditure	Maternal income	Maternal time and workload
Thailand	(Smitasiri and Chotiboriboon, 2003)[8]	Fish, dairy							

[1] Charles Nicholson, personal communication

[2] The same intervention was studied by Ayele *et al.* (Ayele and Peacock, 2003). This paper, however, is very unclear methodologically. It is not clear how project sites and households were selected for the study; the sample size changes for different variables without a clear explanation; there are no statistics and the research methodology is absolutely not clear.

[3] Traditional tea made often of coffee pulp and leaves and preferably drunk with milk (Habtemariam, Ayalew, Habte et al., 2003).

[4] Could not obtain original report: Tilden R. Impact of the FAO vitamin A nutritional improvement project in rural Vietnam on: rates of xerophthalmia, nutritional status, maternal attitude and practices, household production and consumption patterns, and children's dietary practices. Rome: FAO, 1993.

[5] HKI has introduced animal production into existing gardening activities, but only very limited information is available in a 4 page leaflet.

[8] This reference refers to a number of studies in Thailand; none of the reports are available in English.

Impacts on Dietary Intake

The polyculture fish production intervention in Bangladesh had no effect on overall fish consumption, but led to a greater consumption of larger fish. Because small fish are more nutritious than large fish (Roos et al., 2003), this change may actually have decreased the dietary quality (Bouis et al., 1998). There was also no difference in total fish consumption between the fish producing and non fish producing households in the Roos et al.(2003) study in Bangladesh. Thompson et al. (2000) did not measure dietary intake in the intervention and control households in an aquaculture extension project in Bangladesh. Using the reported total production and the proportion of the harvest consumed by the household, intervention households and their neighboring households seem to have consumed more fish. The article does not provide enough information, however, to test this difference statistically.

Alderman (1987) found that households in villages with cooperatives consumed less milk than households in villages without cooperatives. The nutrient consumption of households with cows in intervention villages, however, rose whereas that of non-producing households fell. In the second dairy development project, adequate dietary protein intake was found only in children (1to 4 years) in households producing more than 5 liters of milk per day. Children in households producing less milk were worse off, with the lowest dietary protein intake in the non-milk producing households. The same pattern was found for dietary energy intake, but none of the groups met the RDA requirement. None of the differences were tested statistically (Begum, 1994). Households with crossbred cows in Ethiopia consumed more energy, fat, protein, retinol and iron than non-adopters (Ahmed et al, 2000). In Kenya, women reported increased milk consumption as a consequence of an intensive dairy technology project (Mullins et al., 1996).

The three interventions promoting poultry production had a positive effect on dietary intake. Iron, total protein and animal protein intake were higher in participating than in non-participating households in the agricultural intervention in Egypt (Galal et al., 1987). A semi-scavenging poultry production intervention in Bangladesh found no increase in egg or chicken consumption. The adopting households, however, ate more fish (Nielsen et al., 2003). A poultry production intervention combined with a saving and credit scheme and technical training in Bangladesh resulted in increased consumption of eggs, chicken, fish, meat and milk and grains (Nielsen, 1996). Both studies in Bangladesh suggest that at least part of the effect on dietary intake operated through increased income.

Studies in Ethiopia, Thailand and Vietnam combined the promotion of animal husbandry with the home production of fruits and(or) vegetables and nutrition education. In Ethiopia, children in participating households had slightly more diverse diets and were significantly more likely to drink milk more than 4 times per week. Participating households consumed egg yolk at a low rate of 0.46 per week, but this was significantly higher than in the control households (0.29 times per week). Most produced milk was used in the form of *hoja*, a traditional tea drunk by adults (Ayalew et al., 1999; Habtemariam et al., 2003). In Vietnam, the intervention group had greater intakes of vegetables, fruits, energy, protein, vitamin A and iron (English et al., 1997). The results of the study in Thailand are less straightforward. Vitamin A intake went up in both intervention and control groups, but the increase was greater in the intervention group. Iron intakes increased in lactating women in both the intervention and control group, in two- to five-year-olds in the control group and in 10 to 13-year-olds in the intervention group (Smitasiri and Dhanamitta, 1999). The authors could not explain these inconsistent findings.

It is notable that the studies for interventions targeted to women or with a nutrition education component more consistently reported a positive effect on dietary intake. The agricultural intervention in Egypt was not specifically targeted to women, but half of the poultry farmers turned out to be women (Galal et al., 1987). The exception to this rule is the Alderman (1987) study in India. Begum (1994) reports a positive effect as well, but he does not present any statistical tests or multivariate analyses. The same holds for the Thompson et al. (2000) aquaculture study in Bangladesh.

An important question that is only partially answered in the reviewed studies is whether the reported increase in consumption was a direct effect of increased production or indirect effect of increased income. Alderman found that the increased nutrient consumption of milk producing households was not due to an increase in milk consumption as milk consumption fell in the intervention villages. The effect thus operated through an increase in income. The results of two other studies suggested that this indirect pathway is important: the two poultry studies in Bangladesh found that the consumption of fish increased (Nielsen, 1996; Nielsen, Roos, and Thilsted, 2003). A limitation of many studies was that dietary intake was derived from household level data, ignoring potential intra-household allocation preferences. Finally, many studies were unclear on how dietary intake was measured.

Impacts on Nutritional Status

Only four studies evaluated the impact of livestock-related interventions on nutritional status. The prevalence of iron-deficiency anemia dropped in school-aged children during the period of the agricultural intervention in Egypt (Galal et al., 1987). It is not clear what proportion of these children came from households participating in the intervention. It is plausible, however, that the improvement in iron status was a consequence of the reported increase in ASF consumption in the participating households.

The goat development project in Ethiopia had no impact on child anthropometric indicators, but was found to be associated (no statistics provided) with lower prevalence of night blindness and Bitot's spots (Ayalewet al., 1999). In Thailand, serum samples were collected from school-age girls. Serum retinol and ferritin levels increased significantly in this group. The increase in hemoglobin levels did not reach significance. The improvement in serum retinol levels could be a consequence of the increased intake of vitamin A foods. The improvement in iron status may have been a consequence of the promotion of the consumption of iron rich foods (although no significant improvement in iron intake was recorded). School-age girls were also exposed to a school-based nutrition program including the weekly administration of 60mg ferrous sulfate for 12 weeks and the improvement of the nutrient content of school lunches. As a consequence, the authors could not separate out the contributions of the different dimension(s) of the interventions (Smitasiri and Dhanamitta, 1999). The study in Vietnam found a positive effect on child growth. Children in the intervention were also found to have better dietary intake, and the impact on growth can be reasonably attributed to the intervention (English et al., 1997). As in the study in Thailand, the intervention in Vietnam consisted of a number of different components, and one can therefore not determine whether the animal production component caused the effect.

In sum, the interventions associated with marked improvement in dietary intake and nutritional status belong to two groups: women either played a critical role in the intervention or the interventions included a nutrition education component. The only well-conducted study forming a exception to this rule is Alderman's evaluation of the dairy cooperatives in India (Alderman, 1987). Although the problems in the design, evaluation and analysis of many of the studies form an obstacle in attributing the effects to the interventions, one must note that the importance of women and nutrition education are consistent with earlier findings in the literature. Women tend to be more concerned with the health and well-being of children than men. Ruel (2001) found that the inclusion of nutrition education and behavior change components made interventions more effective. The four studies that investigated the impact on nutritional status found (partially) positive effects. These can be plausibly attributed to the intervention, because the dietary intake improved in those studies as well. Due to the composite nature of two of the interventions, the contribution of the animal production component to the improvement in nutritional status could not be determined.

Impacts on Income and Expenditure

Livestock are the primary form of savings for many households. In times of need, animal sales allow households to generate cash. The sale of animal products such as manure and milk is often an important source of income. Livestock production offers poor people without access to land and capital an opportunity to increase their income. Moreover, small-scale livestock production enables poor people to earn an income from animals fed household waste or grazed on common property pastures (Delgado et al., 1999; International Fund for Agricultural Development, 2004). However, it is important to note that animal production is not without risk, and those risks tend to be greater for poorer farmers. Poor farmers have a limited access to the necessary inputs and hence face higher animal mortality (International Fund for Agricultural Development, 2004).

Seven studies examined some indicator of income or expenditure effects. Bouis et al. (1998) found a positive but very modest income effect in the aquaculture project in Bangladesh. Another aquaculture intervention in Bangladesh found that the returns on investments were higher in extension households, but did not report any household income or expenditure data (Thompson et al., 2000). The dairy cooperative project in India increased household income and expenditure (Alderman, 1987). Market-oriented dairying in Ethiopia reported increases in both food and non-food expenditures. The income of households adopting market oriented dairying was 72% higher than the income of non-adopters. Using instrumented income[9], Ahmed et al. (2000) found that higher income was associated with higher food and non-food expenditures. Women in coastal Kenya reported increased household income from dairy production (Mullins et al.,1996) as well as increases in food purchases, school fee payments and book purchases. The first poultry intervention in Bangladesh reported increases in the sales of chickens and eggs (Nielsen et al., 2003). In the second study on poultry in the same country, the authors found that economic conditions of households had improved, that both food and non-food expenditure increased and that the proportion of income spent on food decreased (Nielsen, 1996).

[9] As income is an endogenous variable (i.e. correlated with the error term in the food and non-food expenditure equations) one would obtain biased regression estimates. Using (proper) instruments to predict income and then using predicted income in the equation of interest addresses this problem.

In summary, all of the studies that reported income or expenditure found a positive association between these outcomes and the intervention. According to the two studies with the strongest methodological design, the Bouis et al. (1998) aquaculture study in Bangladesh found a positive yet modest effect on income, and the Alderman (1987) dairy cooperative study in India, , a positive effect on income and expenditure. Even though the limitations of the other five studies warrant some caution in the interpretation of their results, their reported effects on income and expenditure are consistent with the best conducted.

Impacts on Caregiver Income

It is well recognized that due to intrahousehold resource allocation preferences, increased household income will not necessarily benefit all members of the household equally (Haddad et al., 1997). In addition, many studies have shown that men and women spend income under their control very differently. Women tend to spend a large proportion of their income on food and health care for children and on household consumption goods. Men typically use a larger proportion of their income for personal expenditures. Studies from Africa, Asia and Latin America clearly show that women's income has a significantly greater positive effect on child nutrition and household food security (Quisumbing et al., 1995).

The importance of livestock production for women's income in developing societies has been shown by a large number of studies. A review of the findings of the Small Ruminant Collaborative Research Support Program (SR-CRSP) in Peru, Bolivia, Indonesia and Kenya found that women were the major managers of small ruminants in most production systems. Women (at least partially) owned the animals in all locations. In contrast, cattle were never owned only by women. Milk, and sometimes the income from milk, however, was under the control of women. Control over the income from small ruminants was invested directly on either household consumption or school supplies (Valdivia, 2001). In the central highlands of Ethiopia, 60% of the families were found to keep chickens. Women owned and managed the chickens and controlled the cash income from the sales (Dessie and Ogle, 2001). Although women in Africa are generally the main owners of poultry, they seldom have full control over the resulting income and benefits (Gueye, 2000).

Three intervention-related studies examined the impact of animal husbandry on maternal income or women's control over income. The qualitative study on cage aquaculture in Bangladesh found that the impact on women's income and control varied greatly between regions, villages and households. Unfortunately, the authors did not investigate the determinants of this variation (Brugere et al, 2001). Another study in Kenya found that an important share of the additional income from intensified dairying was under women's control. In Ethiopia, however, men's incomes benefited significantly more from intensified dairying than women's (Tangka et al., 1999). Women from households participating in the intensive dairy technology project in Kenya reported increases in both household income and women's personal income. The higher income was accompanied by increased food purchases, school fee payments and book purchases (Mullins et al., 1996). Finally, women in one of the poultry in Bangladesh reported to have gained influence in deciding on the use of income (Nielsen, 1996).

A concern of a number of authors is that the market orientation of smallholders may lead to women losing control over income to men (Huss-Ashmore, 1996). Tangka et al. (1999) found no evidence of this in Ethiopia and Kenya. However, Nicholson et al. (1998) found that income from milk marketed as fluid milk through local dairy cooperatives in the Ethiopian highlands was controlled by men, whereas income from dairy products processed at home by women was under their control. It is important to note also that women's livestock ownership rights may not be as stable as men's. In general, stress and constraints lead to an erosion of women's ownership rights, since women's ownership of livestock is often considered a "secondary right". Evidence from around the world shows that pastoral women's rights in and their control over livestock management and marketing are being eroded (Niamir-Fuller, 1994).

In conclusion, women's control over income from livestock production activities is very site and production system-specific. Livestock provides a real opportunity for women to increase their income in some situations. In other situations, however, it merely leads to a significant increase in women's workload (see below), without a considerable effect on their control over the additional resources. The evidence from intervention studies is very limited, and does not allow us to draw any conclusions. A final concern is that both success and economic stress may lead to women losing their control over income from animal production.

Impacts on Caregiver Time and Workload[10]

Women perform most of the work of food production in the developing world. They contribute more than half of the labor required to produce the food consumed, in Sub-Saharan Africa up to 75%. African women perform most of the work of processing food crops, food storage, transport from farm to village, hoeing and weeding. In Asia, women provide between 10 and 50 percent of labor for different crops. In Latin America, women contribute significantly to peasant agriculture. They also play an important role in harvesting, post-harvest processing and marketing (Quisumbing et al., 1995). Above and beyond the burden of food production, women play a critical role in food preparation, collecting water and fuelwood and providing childcare (Quisumbing et al., 1995). The time constraints of women in developing countries have been described as a zero-sum game. New activities can only be accommodated if another activity is dropped or performed more time efficiently (McGuire and Popkin, 1989).

Reasonable work loads and adequate time availability are factors determining the ability of mothers or caregivers to provide adequate childcare and have been labeled a "resource for care" (Engle et al., 1999; Jonsson, 1995). The introduction of livestock production may result in a larger income controlled by women which may be translated into higher food consumption, but these benefits may be offset by a decrease in time spent on childcare (Quisumbing, 1998). Given the high demands on women, interventions aiming at increasing animal production in developing countries will need to consider the role of women carefully. No studies examined the impact of livestock promotion interventions on caregiver time spent on childcare. Two aspects of this relationship, however, have been studied: the role of maternal time and labor in livestock production, and the impact of maternal workload on childcare and child wellbeing.

Making generalizations about the role of women in livestock production is difficult, even on a regional basis. African women for instance are often thought to take care of small animals (e.g.

[10] Although none of the reviewed intervention studies examined these outcomes, the discussion of other literature on this topic is included here for consistency with the previous sections.

chickens, small ruminants) and men take care of cattle. There are, however, many variations between ethnic groups and regions. Niamir-Fuller (1994) distinguished a number of general patterns:

- Women's role in livestock production in developing countries has been systematically underestimated;
- Women in transhumant and agropastoralist groups are responsible for livestock at the homestead, for small animals (e.g. poultry, pigs) and for the processing and marketing of livestock, including milk. In strict Muslim societies, however, marketing tends to be the role of men;
- In intensive livestock systems, women are responsible for more than three quarters of the livestock related tasks. In Latin America, however, men control the capital-intensive operations;
- Small-scale peri-urban operations are owned and run by women, except in strict Muslim societies. Large-scale peri-urban systems are dominated by men;
- In Africa and the Middle East, women's ownership rights are systematically smaller than their labor contributions would warrant. On the other hand, in Latin America and far East Asia, women have more control over animals;
- An important factor contributing to the increase in women's role in livestock production and their workloads is the migration of men to find seasonal work (especially in Latin America and Asia) and the displacement of pastoral households (especially in Africa);

Given the important role of women in livestock production, one would expect the introduction of livestock or the intensification of an existing livestock production system to result in an increased workload for women. Only a small number of studies have investigated this association.

The qualitative study on cage aquaculture in Bangladesh found that women were responsible for time-consuming activities such as the collection and preparation of feed (Brugere et al., 2001). It is not clear whether women's total time burden increased, and whether theere were any impacts on childcare activities. Women in an intensive dairy technology project in Kenya, reported that intensive dairying improved household welfare, mainly through increases in household income and milk consumption. There was broad consensus, however, that these benefits came at the expense of a higher workload for women. It is important to note that the authors did not collect time allocation data directly, but that these findings were based on qualitative impressions of time allocation. The authors of this small study (32 households were interviewed) further reported that "neither housework nor childrearing showed any substantial change after the introduction of the intensive dairy enterprise" (Mullins et al., 1996). It is not clear, however, whether this statement is related to the amount of time spent on or the level of responsibility with respect to these activities. Another important aspect, the quality of childcare, was not evaluated. Subsequent research on the impacts of dairy cattle ownership in this same area, however, found that household members did not spend more time on cattle-related tasks if they owned crossbred animals (Nicholson et al., 2004). Household labor requirements increased for higher-productivity dairy cows, but additional labor was provided by hired labor. Unpublished findings from the same authors indicate that women and children did not spend more time on cattle-related tasks in the coast area of Kenya. On the other hand, similar data from the Kenyan highlands suggests that women's workloads did increase (Nicholson, 2005). In Ethiopia, women's dairy-related labor was not different between households participating in market-oriented smallholder dairying (i.e. with crossbred cows) and households with locally bred cows (Tangka et al., 1999).

In conclusion, women play an important role in livestock production. The specific nature of women's responsibilities varies widely by region, ethnic group and production system. There is a real chance that introducing livestock production or intensifying current production systems leads to an increase in women's workload, but this is not a general pattern. The reviewed studies, although very limited in number, confirm this pattern. One important factor that has not been studied is that livestock activities may offer an advantage as they may be located on the homestead or very nearby. This means that moving to livestock production may allow women to work closer to home, as opposed to crop production or off-farm employment.

Impacts on Maternal Labor Participation, Childcare and Child Well-being

Most studies on maternal labor market participation have reduced the discussion to a trade-off between potential positive effects of increased income earned by the mother and the potentially negative effects of the decrease in time available for childcare. Engle and Pedersen have argued that this approach ignores several important issues. First, there is the self-selection of women who decide (not) to work. Second, one cannot simply compare working with non-working mothers, because working conditions may differ considerably with respect to the possibility to provide childcare. And third, the availability and quality of alternate childcare needs to be taken into account as well (Engle and Pedersen, 1989). A statistical problem with most studies is that they do not control for the endogeneity of the mother's decision to participate in the labor market. This could lead to biased estimates of the nutritional impacts of labor force participation (Glick and Sahn, 1998).

A previous review of the literature concluded that maternal labor force participation had no significant effect on child nutritional status (Leslie, 1988). The conflicting findings of the studies in that review, however, probably underline the importance of contextual variables. The handful of studies that controlled for endogeneity provides conflicting results as well. In Thailand, the number of hours of formal-sector work had a negative effect on child nutritional status. Participation in the informal sector at home was positively associated with child nutrition (Chutikul, 1986). Blau et al. (1996) showed a positive association between maternal employment and child health in the Philippines. The income effect seemed to offset the harmful effect of reduced breastfeeding. In the capital city of Guinée-Conakry, Glick and Sahn (1998) found a positive effect on child height as a consequence of increased income, and a negative effect due to reduced time for childcare. The overall net effect of maternal employment was negative. Notwithstanding the inconsistent findings in the literature, Engle and Pedersen (1989) stressed that very young children are at risk of poor growth if their mothers are engaged in time intensive activities, if they have little control over resources and do not have access to high quality alternate childcare.

Review of Studies Not Related to Livestock Interventions

Impacts of Livestock Ownership on Child Nutritional Status

Nicholson et al. (2003) previously reviewed studies assessing linkages between livestock (primarily dairy animal) ownership, consumption and child growth. Key relationships examined in that review included the role of dairy consumption in child nutrient intake, the allocation of milk production between sales and household consumption, the relationship between income, food expenditures, and household nutrient availability, and household labor allocation. A number of studies not directly linked to livestock interventions have also examined livestock production as a determinant of child nutritional status or child mortality, especially ownership of dairy animals (Hitchings, 1982; Vosti and Witcover, 1991; Vella et al., 1992; Leonard et al., 1994; Gross, 1998a and 1998b; Nicholson et al.,1999). Table 3 summarizes the key features and relevant findings from these studies. Various types of econometric models (OLS, Seemingly Unrelated Regressions (SUR), Random Effects) were developed using height-for-age z-score (HAZ), weight for height Z-score (WHZ) and weight-for-age Z-score (WAZ) as indicators of nutritional status. HAZ is generally considered an indicator of long-term, cumulative nutritional status, whereas WHZ reflects short-term, immediate status. WAZ captures elements of both. Logistic model formulations were used to examine impacts of animal ownership on mortality. The results of these studies are generally consistent despite regional differences. Dairy animal ownership had a significant, positive effect on HAZ and decreased the probability of child mortality. Dairy cow ownership was not found to be a statistically significant determinant of WHZ. Ownership of other types of animals was not found to be a significant predictor of stunting or wasting, although the classification of this variable was not always clear or consistent in these studies. This suggests that future studies should give more attention to past livestock ownership and ASF consumption when examining the determinants of stunting.

Nicholson et al. (2003) examined the nutritional impacts of cattle and dairy cow ownership using comparable datasets from coastal and highland Kenya. They found that, controlling for other factors, cattle ownership increased HAZ of pre-school children between 0.29 and 0.85 standard deviations (depending on the region and the econometric model formulation)[11]. There was no statistically significant impact of cattle on WHZ. The impact of dairy cow ownership on HAZ was smaller and more ambiguous: SUR models indicated a statistically significant positive effect of 0.26 standard deviations for children at the coast, but no statistically significant effect in the highlands. Thus, the available evidence suggests that cattle and dairy cows may have positive impacts on longer-term status (HAZ) in some environments, but little effect on short-term well-being (WHZ).

[11] Attribution of impact in these reduced-form econometric studies derives from the economist's definition of causality, but is also consistent with the Habicht et al., concept of a "plausibility assessment."

Impacts of Dairy Cattle Ownership on Other Outcomes

Nicholson et al. (2004) examined various outcomes related to the ownership of grade or crossbred dairy cows[12] in coastal Kenya. Data on milk production, consumption, cash income, labor allocation to cattle, and preschooler nutritional status were collected for a random sample of nearly 200 households with and without dairy cows in three coastal districts. Econometric models[13] using these data indicated that dairy cow ownership had statistically significant positive effects on milk production, milk consumption, and household cash income (especially from dairy product sales). The impacts on milk production and income were particularly large and positive. Income from non-agricultural sources was unaffected. For households owning cattle, ownership of dairy cattle increased the total time allocated to cattle-related tasks about 165 minutes per week for each dairy cow owned. However, households with dairy cattle actually spent less total time in cattle-related tasks, and hired labor allocated to cattle tasks made up the difference.

Nicholson et al. (2004) also noted that in coastal Kenya the increased milk produced by households with dairy cows resulted in increased milk sales with small increases in milk consumption. This provides circumstantial evidence of the potential importance of indirect effects on child nutrition, i.e., through increased income and changes in allocation of land and household labor. Huss-Ashmore (1992) indicated that the contribution of milk to household macronutrient availability was small, but could be notably more important if milk were provided preferentially to children. In addition, she determined that price relationships for maize and milk in coastal Kenya in the early 1990s were such that households could increase energy and protein availability by selling milk and purchasing grains and pulses. This latter result also suggests that indirect effects may be more important than just increased milk consumption. However, this calculation does not consider that the bioavailability of protein and micronutrients found in milk (especially vitamins A and B_{12}) is better than that in grains and pulses.

Most other studies have found that ownership of dairy cows increases household income, sometimes substantially (e.g., Leegwater et al., 1991; Mugo, 1994). However, many previous authors have noted that the linkage between increases in income and nutrient consumption may be weak due to increasing expenditures on non-food items, increases in the costs of nutrients purchased, and shifts in income control (Behrman, 1988; Bouis, 1994; Kennedy, 1994). These "leakages" suggest that even if dairy cow ownership increases incomes, this may not significantly improve child nutritional status.

[12] This is not considered an "intervention-related" study because a substantial proportion of the dairy cow owners surveyed had not previously participated in the National Dairy Development Project (NDDP) and so had adopted dairying on their own.

[13] Heteroskedastic Tobit and Censored Least Absolute Deviations (CLAD) formulations were contrasted.

Table 4. Summary of Selected Studies on Livestock Production and Nutritional Status Not Related to Livestock Interventions

Country	Reference Concerns with Methods	Design and Methods[1]	Impact on Dietary Intake and Nutritional Status
Kenya (Highland tea and coffee zones east of the Rift Valley)	Hitchings (1982) Coefficients may be biased due to endogeneity and omitted variables; variable selection somewhat ad hoc.	Anthropometric measurements, cropping patterns and socio-economic data for N=59 (tea zone) and N=144 (coffee zone) children 1 to 4 years, Stepwise multiple regression for land area devoted to various crops, number of cows and other cattle owned by breed group and household size.	*Tea zones:* • Number of grade cows owned had a statistically significant positive effect on height-for-age as a percentage of the Harvard standard height (+1.71 percentage points per cow) • Number of grade cows owned had a statistically significant negative effect on weight-for-height as a percentage of the Harvard standard (-0.23 percentage points per cow) • Number of native cattle owned had a statistically significant positive effect on height-for-age (+1.68 percentage points per cow) and weight-for-height (+2.31 percentage points per cow) *Coffee zones:* • Number of native cows owned had a statistically significant positive effect on height-for-age relative to the Harvard standard (+0.92 percentage points) • No statistically significant effects attributed to grade cows or cattle
Kenya (Kilifi District)	Leegwater et al. (1991) Effects cannot be attributed entirely to income, cattle ownership or milk consumption due to other differences not controlled for.	Anthropometric measures and socio-economic data from N=44 children in households participating in NDDP; N=39 children in households regularly purchasing milk from NDDP farmers; N=138 children in households from the general population, for all children in these households aged 6 to 59 months. Comparison of group means and distributions by household category.	• Mean height-for-age as a percentage of the WHO standard was higher for NDDP farmer and NDDP customer households than for the general population •No statistically significant differences in mean weight-for-height as a percentage of WHO standard for the three types of households • For households with income 1,500-3,999 KSh/consumer unit, mean weight-for-height as a percentage of WHO standard was higher for the combined group of NDDP farmer and customer households
Kenya Coast and Highland	Nicholson et al. (2003) Use of statistical controls rather than controlled experimentation.	Anthropometric measures from children in random samples of households with and without dairy cattle; N=198 in coastal Kenya and N=172 in highland Kenya. OLS, Random Effects and Seemingly Unrelated Regression econometric models to examine the impact of number of cattle and dairy cows on HAZ and WHZ	• Cattle ownership had a large and statistically significant positive effect on HAZ in both regions • Dairy cow ownership had a large and statistically significant positive effect on HAZ for children in the coast region, but not the highlands

Country	Reference Concerns with Methods	Design and Methods[1]	Impact on Dietary Intake and Nutritional Status
Ecuador Coastal Zone	Leonard et al. (1994) No allowance made for impacts of different animals; small sample size; coefficients may be biased due to endogeneity and omitted variables; variable selection ad hoc.	Anthropometric measures and socio-economic data from N=43 children 0 to 6 years. Stepwise multiple regression (i.e., variables with p>0.10 included).	• Combined number of cows, pigs, and chickens owned by the household had a statistically significant effect on HAZ (+0.24) in a model including child's age, per capita household food expenditures, and an intercept term
Uganda (Mbarara District)	Vella et al. (1995) Models include morbidity as an explanatory variable, so results may be affected due to endogeneity.	Anthropometric measurements, morbidity data and socio-economic data from N=4320 children 0 to 59 months. Multiple regression.	• Ownership of cows (binary variable) had a statistically significant impact on HAZ (+0.298 standard deviations) • Ownership of cows had no statistically significant effect on WHZ
Rwanda	Grosse (1998) Coefficients may be biased due to endogeneity and omitted variables; variable selection ad hoc.	Anthropometric data from 1992 for N=542 children 24 to 59 months, agro-economic data from 1990-91 crop years for the households involved. Comparisons of livestock ownership groups and multiple regressions controlling for cluster (random) effects.	• Children in households with cattle or goats had higher mean HAZ scores and a lower prevalence of severe stunting (not controlling for other factors) • A discrete dairy animal ownership index [0=no goats or cattle; 1=goats only; 2=cattle] had a statistically significant positive effect on HAZ (+0.287 standard deviations) in multiple regression models controlling for maternal height, maternal education, per capita income quartile, and housing characteristics

[1] Includes a brief summary of only methods related to the results reported in this table, not all methods reported in the document.

As noted above, the impacts of dairy cow ownership on household labor allocation (and their relationship to gender roles) may be important determinants of child nutritional status. Consistent with much of the literature on both technology adoption and commercialization of smallholder agriculture, there have been concerns about the effects of dairy production on the workload of women and children. A number of studies have suggested that dairy cow ownership increases time allocated to cattle-related tasks, especially in the cut-and-carry forage systems promoted under the NDDP in Kenya (Mugo, 1994; Maarse, 1995), but the one study with detailed information on time allocated to cattle-related tasks suggests mixed results (Nicholson et al., 2004). The extent to which increased time allocated to cattle has affected time allocated to food crop production, other income-generating activities, or the quality or quantity of care and feeding for children is uncertain in the absence of information about overall time allocation by all household members (Tangka et al., 2000). .Overall, the reviewed studies not related to livestock interventions suggest that livestock ownership increased ASF intake, markedly increased household incomes, and had varying effects on women and children's time allocation.

Relationships between Animal Source Food Production and Consumption

As indicated in Figure 4 and discussed in the review above, a key linkage between livestock production and nutritional status is the allocation of livestock products—particularly meat and milk—between consumption of own production and sales. Thus, this issue is singled out for additional detailed discussion here using information from studies of livestock-related interventions and non-intervention studies. Published research examining the relationship between ASF production and consumption and household nutrition appears to be largely cursory or indirect (Rajendran and Prabahran, 1993; Sharma, 1994; Gupta, 1995; Valdivia et al., 1995; Stemmer and Zarate, 2000; Ayele and Peacock, 2003; Nielson et al., 2003; Sharma et al., 2003). The majority of the studies reviewed simply compared the means of production and consumption and(or) sales of ASF across region, income, land wealth, or temporally with respect to an intervention. Some of the studies did describe factors that are believed to influence the consumption versus sales decision, but these factors were not typically tested statistically. Thus, the existing literature does not appear particularly insightful about what household-level factors determine how much is produced and what percentage of ASF is kept or sold. This is particularly troublesome in studies where sampling methods are questionable. These studies do, however, draw from a diverse array of countries and find roughly similar results across these countries. Therefore, this information is useful in deriving a rough sketch of the sales versus consumption decisions in ASF-producing households. It is worth noting that previous studies on general food expenditure patterns, for example those using econometric models based on the agricultural household model frameworks, may in fact provide additional insights into this issue. These more general studies were not reviewed in any systematic way as a part of this review.

As a metric to summarize the findings of the studies, the concept of arc elasticity of consumption from own production with respect to production is used. The arc elasticity is calculated as the percentage change in consumption divided by the percentage change in production, where the changes are measured between groups with different production technologies, program participation, farm size or other factors. It is important to note that these calculations in most cases do not control for (or explain) variations in other factors that will influence the consumption versus sales decision. Thus, they should be regarded as preliminary evidence as to how ASF consumption responds to changes in production.

Over three-fourths of the calculated arc elasticity values are below 1.0, and well over half fall between 0.3 and 0.5 (Table 4)[14]. This suggests that the response of ASF consumption from own production often is inelastic (less than proportional to production), so that the proportional increase in sales—and therefore revenues—will be larger[15]. This qualitative result again suggests that the income generated from increased sales may have an important effect on household nutrition. This is supported by a study that compared calorie, protein and iron elasticities for households with and without crossbred dairy cows and found that these nutrients had relatively more elastic responses to increased cash expenditures on food than from home ASF production (Ahmed et al, 2003). It is not yet known whether these effects exist for other livestock species or products with characteristics different from those of milk and dairy products. However, there appears to be a broad range of responses to increased ASF production depending on the region and the specific livestock species. The finding of generally inelastic consumption responses should be conditioned by regional taste preferences as well, due to the high proportion of non-traditional ASF interventions included in this summary. Only one study reviewed addressed the ASF consumption versus ASF production question directly using econometric methods (Nicholson et al, 2004). In a reduced-form Heteroskedastic Tobit model and a Censored Least Absolute Deviations model, ownership of a dairy cow (an effective proxy for increased milk production of 5 liters per day) was found to significantly increase milk consumption by between 1 to 1.4 liters per day. Estimated arc elasticities of these results are included in the discussion above.

In the reviewed studies, three main factors were mentioned within many of these studies as having universal relevance to the sale versus consumption decision. Market access is the most mentioned factor, conditioned by cultural norms and the dual purpose of livestock as a banking system, particularly small livestock. It is recommended to conduct a more thorough review of previous studies that examine food consumption and expenditure patterns to determine whether those studies provide additional evidence on both the degree to which ASF consumption increases with ASF production, and the key explanatory variables. It will likely also be useful to undertake additional analyses using previously collected household data in a variety of regions, species and production systems to better understand these relationships. Our brief review of the relationships between production and consumption of ASF does not answer some quite relevant questions, such as whether increases in consumption are nutritionally meaningful, and(or) for which household members. Assessment of these questions would require additional information on household composition and individual consumption of all foods, which were not available in the reviewed studies.

[14] Note that it may be informative to examine whether differences exist in arc elasticities between studies based on panel data and those based on cross-sectional data, but this has not be done herein.

[15] It can be shown that the relationship between the elasticity of consumption with regard to production and the elasticity of sales with regard to production is given by $\varepsilon^{SP} = 1 + (Q^C/Q^S)\cdot\varepsilon^{CP}$., where Q^C and Q^S are the quantities of consumption and sales, respectively. This implies that if the response of consumption to production is inelastic (less than 1), the response of sales to production will be elastic (greater than 1).

Table 5. Estimated Arc Elasticities of Consumption With Respect to Production, Selected Reviewed Studies

Area/Study	Comparison Considered	Production				Consumption				Arc Elasticity
		Baseline	Alternative	Change	% Change	Baseline	Alternative	Change	% Change	
Nicholson et al.(2004) Coastal Kenya	Milk from local versus dairy cows, lts/month	110.5	623.5	+512.4	+464	14.5	100.6	+86.1	+594	1.3
Nicholson et al.(2004) Highland Kenya	Milk from local versus dairy cows, lts/month	125.5	288.5	+163.0	+130	78.5	113.4	+34.9	+44	0.3
Ayele et al. (2003) Ethiopian Highlands (Gorogota)	Milk under goat intervention (pre- and post-intervention), litres per person per year	359.0	434.5	+75.5[1]	+21	20.9	35.9	15.0	+72	3.4
Nielsen et al. (2003) Female Bangladeshi households	Eggs, households adopting poultry technology, eggs per month	12	30	+18	+150	4	7	+3	+75	0.5
Bekure et al (1992) Maasai Herders	Value of ASF production, “rich” versus “poor” households, KSh per year	15,381	68,891	+53,510	+348	6,780	13,858	+7,078	+104	0.3
Shapiro et al. (2000) Ethiopian Highlands (Holetta)	Milk for households with and without crossbred cows, litres milk equivalent per adult equivalent per week	0.34	4.07	+3.73	+1,097	0.13	0.55	+0.42	+323	0.3
Sharma et al.(2003) North India	Milk from households with small and large landholdings, liters per day	8.8	54.9	+46.1	+524	2.8	7.7	+4.9	+175	0.3

Area/Study	Comparison Considered	Production				Consumption				Arc Elasticity
		Baseline	Alternative	Change	% Change	Baseline	Alternative	Change	% Change	
Sharma et al.(2003) West India	Milk from households with small and large landholdings, liters per day	15.3	75.4	+60.1	+393	1.9	5.1	+3.2	+168	0.4
Sharma and Singh (1994) Himachel Pradesh, India	Milk from households with larger and smaller land assets	6.0	17.7	+11.7	+195	2.3	4.9	+2.6	+113	0.6
Sharma and Singh (1994) Himachel Pradesh, India	Milk from cattle improvement project participants and non-participants, litres per household per day	4.6	10.0	+5.4	+117	1.9	3.2	+1.4	+74	0.6
Gupta (1995) Rajasthan, India	Milk from landless labor versus large farmers	4.5	11.9	+7.4	+164	4.3	7.9	+3.6	+84	0.5
Rajendran (1993) Tamil Nadu, India	Milk from landless labor versus large farmers	4.9	8.1	+3.2	+65	0.3	1.5	+1.3	+433	7.5

[1] Given the large magnitude of this change, an error in reported information seems possible.

CHAPTER 5: THE RELATIONSHIPS BETWEEN LIVESTOCK PRODUCTION AND NUTRITIONAL STATUS RELATED TO DISEASE TRANSMISSION AND ENVIRONMENTAL TOXINS

Zoonoses

Zoonoses are defined as "those diseases and infections which are naturally transmitted between vertebrate animals and man" (Joint WHO/FAO Expert Committee on Zoonoses, 1959). Zoonotic infections have been identified in all major groups of infectious agents (prions, viruses, bacteria, protozoa and helminths) (Taylor et al., 2001). Zoonoses may be transmitted through direct contact with the animal, such as ingestion of animal tissue, skin contact or a bite. Examples include rabies, tularaemia and trichinellosis. The transmission of indirect zoonoses involves a vector or vehicle. Examples of indirect zoonoses are the plague (*Yersinia pestis*) and West Nile virus. Some infections (e.g., tularaemia) can be transmitted both directly and indirectly (Wilson, 2001).

Zoonoses and Poverty

A number of factors make poor people more prone to zoonoses. Poverty and unsanitary living conditions may increase exposure to water-borne and other indirectly transmitted zoonotic pathogens (Feachem, 1983; Perry et al., 2002). Animals are often kept in close proximity to people (mainly for security), frequently sleeping in the same building or room. Poor people are also more likely to consume animal foods that are produced using poor hygiene and in the absence of veterinary services (Coleman, 2002). Furthermore, undernutrition reduces the immune response and hence increases susceptibility to infections. This has been exacerbated further by the spread of HIV, which has increased the prevalence of immuno-suppressed people, creating an opportunistic niche for zoonotic infections (Coleman, 2002). It is important to note that zoonotic infections are not limited to rural areas. Urban agriculture and the raising of livestock are growing phenomena in many cities and might increase exposure to animal excreta and abattoir wastes. Rabies and particularly food and water-borne zoonoses are thus likely to become increasingly important (Coleman, 2002; Cotruvo et al., 2004).

Classification of Zoonoses

Coleman (2002) groups zoonoses according to the degree to which animals are a maintenance reservoir. In the first category, the animal host is the only maintenance reservoir. Eliminating the disease in the animal population or blocking of the transmission between animals and humans will thus eradicate the disease in humans. An example is rabies. Rabies is rarely transmitted between humans. Effective control of rabies in animals in many developed countries has reduced the number of human cases to a handful each year. The second category comprises zoonosis where both zoonotic and anthroponotic transmission are important modes of infection. As a consequence, fully controlling the animal reservoir may not be adequate to eradicate the disease in humans. Examples include leishmaniasis and schistosomiasis. In the third category, the animal reservoir is not important for the maintenance of the disease. Even though malaria caused by many *Plasmodium* species may be classified as zoonotic, prevention of the disease is mainly concentrated on humans.

Examples of Livestock-Zoonoses Linkages from Developing Countries

A case-control study in a peri-urban district in Guinea-Bissau showed that *Cryptosporidium* diarrhea in children was significantly associated with keeping pigs. In this area, pigs were not kept in pigsties but roamed around and often slept in the same room with humans. *Cryptosporidium* oocysts were found in twenty percent of the collected pig feces (Molbak et al., 1994). In a case-control study in rural Malaysia, the presence of chickens (possibly infected with *Salmonella* and *Campylobacter jejuni*) and cats (possible carrier of *Campylobacter jejuni*) inside the house was associated with an increased risk of diarrhea (p=0.06). The analyses controlled for age and sex and a number of socio-economic variables (Knight et al., 1992). Untreated night soil is used as feed in aquaculture in many countries. Contamination with pathogens and eggs of parasites can infect fish and consequently pose health risks to people consuming raw fish from ponds fertilized with night soil. The infection rate with *Clonorchis sinensis* (a trematode) in a number of provinces in China where people consumed raw or undercooked fish reached 70% (Ling et al., 1993).

The Public Health Importance of Zoonoses

The dearth of basic information on zoonotic diseases in developing countries makes quantitative assessments of the relative public health importance practically impossible (Coleman, 2002). The discussion of the public health impact of zoonoses is therefore rather general. An indication of the potential significance is given by the work of Taylor et al. (2001). They found that nearly two-thirds (61%) of all infectious organisms known to be pathogenic to man are zoonotic. In the group of pathogens considered to be “emerging”, an even higher proportion (75%) is zoonotic.

The disability adjusted life year (DALY) is a measure used to compare the relative burden imposed by different diseases. The DALY’s for a given disease integrates the years of life lost and the years of life lived with disability. The WHO published DALY estimates for 27 infectious diseases in 2000. Using the 1959 definition of zoonoses, 20 of these 27 infectious diseases can be classified as zoonotic, but 13 of these 20 fall in the third category defined by Coleman, i.e. the animal reservoir is of limited importance. For the remaining 7 (hepatitis, trypanosomosis, leishmaniasis, schistosomiasis, hookworm, Japanese B encephalitis, Chagas disease), veterinary control would profoundly reduce the burden of the disease. These seven zoonoses together make up 12 million DALY’s, a burden comparable to the burden of tetanus and pertussis. All seven diseases, however, probably have a significant anthroponotic component, i.e. they fall in the second Coleman (2002) category. As a consequence, one cannot determine the zoonotic component of the burden.

Livestock Production and Zoonosis Risk

The significant increase in the demand for animal protein in developing countries will lead to a significant growth in animal production (Delgado et al., 1999). There is wide agreement that the incidence of zoonoses may increase as a consequence of the expansion and intensification of animal production (Bolin et al., 2004; Delgado et al., 1999; Ludwig et al., 2003). There is, however, a paucity quantitative evidence for an association between animal husbandry and zoonotic infections. There do not appear to be any studies investigating this association in developing countries. However, three examples show the adverse effects of intensive livestock production on zoonoses.

First, the high and increasing number of cases of campylobacteriosis in New Zealand has been attributed to the growing livestock production. Low levels of *Campylobacter* have been detected in some water supplies. Furthermore, several studies have documented an association between water supplies and campylobacteriosis outbreaks where the raw water supply was exposed to farm animal runoff (Till and McBride, 2004). Second, an outbreak of the Nipah virus in Malaysia resulted in 256 human infections, 105 of whom died of encephalitis. Fruit bats have been identified as the animal reservoir. The virus was introduced into pigs and close contact between pigs in intensive farming led to transmission between animals and ultimately to transmission to humans (Ludwig et al., 2003). Finally, the application of antibiotics in intensive animal production has caused selection for multidrug-resistant strains of bacteria. The use of antibiotics in poultry production for instance has led to the emergence of resistant *Lysteria*, *E.coli* and *Salmonella* (Delgado and et al., 1999).

Zooprophylaxis and Zoopotentation

The introduction of livestock can have important effects on the ecology of disease vectors (such as *Anopheles* mosquito, the malaria vector) and hence on the epidemiology of the diseases they transmit. Predicting the impact on disease transmission, however, is complicated. The introduction or intensification of livestock may increase the mosquito population through increased success of blood-feeding or the creation of habitats suitable for mosquito larvae. Consequently, this may raise the transmission of vector-borne diseases to humans. On the other hand, cattle may lead to zooprophylaxis against a disease. Zooprohylaxis is defined as the use of animals that are not the reservoir hosts of a specific disease to divert blood-seeking mosquito vectors from the human host of the disease (Service, 1991). In a study in Kenya, for example, Mutero et al. (2004) found higher mosquito vector numbers, but lower malaria prevalence in villages with rice irrigation and than in villages without, and attributed this counter-intuitive result to the presence of cattle kept in the irrigated areas.

Most studies on zooprophylaxis have examined the effect of animals on malaria transmission. The results of these studies are ambiguous. The presence of dogs had a protective effect in Sao Tome (Sousa et al, 2001). A paired cohort study in the Gambia found no association between the presence of cattle and the prevalence of *Plasmodium falciparum* or parasitaemia (Bogh et al., 2002). In Pakistan, malaria prevalence in children was higher in households with cattle. At the village level, there was a positive association between the proportion of households keeping cattle and parasite rates (Bouma and Rowland, 1995). An important limitation of these studies is that they are all observational. Associations, or the lack thereof, may thus be due to inadequate control for possible confounders such as socio-economic status and access to health care. There are apparently no studies on this topic.

The inconsistent results indicate that the potential of zooprophylaxis is very site-specific and depends on many environmental factors. This is confirmed by two mathematical models. The model in Sota and Mogi (1989) predicted a potential increase in malaria transmission as a consequence of the introduction of animals. The model further suggested that only when an extremely large number of animals was introduced, malaria endemicity would be lowered.

Similarly, a more recent model by Saul (2003) predicted that depending on the situation, the impact of the presence of animals could range from a (small) zooprophylactic effect to potentiating disease transmission.

Environmental Toxins

In regions where pollution is a problem, there may also be public health concerns relating to the interaction between animal source foods, specifically meat, and environmental toxins. Environmental toxins such as pesticides and heavy metals tend to accumulate in animal fats, livers and lung tissues (Covaci and Schepens, 2004, Salt Institute)[16]. There is some evidence that the increase in heavy metals such as strontium, manganese and zinc (commonly found in pesticides) in the drinking water is inhibiting the absorption of iron (Small et al., 2001, Basedaghat, 2002, Hashizume et al, 2004). Other studies on the increase of pollutants in women's blood and breast milk note a concurrent high prevalence of iron-deficiency anemia in the sample, although not enough information was available to test the relationship between the two (Ataniyazova et al, 1999).

Conclusion

The introduction of animals could lead to an increase in zoonotic infections and in malaria endemic areas to increased rate of malaria transmission. To our knowledge, no intervention studies have been conducted on either of these outcomes. Current understanding does not allow us to predict the impact of promoting animal husbandry on the spread of zoonotic infections. In malaria-endemic areas, the introduction of livestock could range from a zooprophylactic to a potentiating effect on malaria transmission. It is clear that more research needs to be done to advance our understanding.

Despite the lack of evidence, there are many reasons to proceed with caution when promoting animal production in developing countries. Nearly two-thirds of all infectious organisms pathogenic to man are zoonotic. An even higher proportion of zoonotic agents is found in the group of emerging pathogens. Furthermore, there is wide agreement that the importance of zoonoses will increase as animal production grows. Finally, unsanitary living conditions, close proximity to animals, the lack of veterinary services and an increased susceptibility to infections as a consequence of undernutrition and disease make poor people especially prone to zoonoses. The information available to date suggests that concentration of environmental toxins in meat is a potential concern, but the specific effects of meat consumption on this dimension of human health are probably site-specific and are currently unknown. The uncertainty in the current state of knowledge implies that livestock-related interventions should explicitly plan to monitor for possible negative health effects.

[16] The pollutant load was found to be largely carried in the adipose tissue, with the exception of PCBs, which concentrated in the lungs and liver.

CHAPTER 6: SUMMMARY AND IMPLICATIONS

The purpose of this chapter is to provide a succinct summary of the findings with regard to the linkages between livestock ownership and nutritional status, to suggest guidelines for future interventions, and to outline future research priorities.

Summary of Findings

Impacts of Animal Source Food Consumption

ASF are an excellent source of high-quality protein. They are also rich in micronutrients such as iron, zinc, vitamin A, riboflavin, vitamin B12 and calcium. In addition, micronutrients are more bio-available from ASF than from plant source foods. The nutritional benefits of consuming ASF are not limited to the positive effects on infant and child growth. Diets including ASF can help prevent common nutrient deficiencies negatively affecting pregnancy outcomes, lactation, child morbidity and mortality, cognitive development and school performance and adult work and care-giving capacity. In malnourished populations, the risk of increasing chronic disease risk through the addition of meat or dairy to the diet is unlikely to outweigh the nutritional benefits.

Impacts of Livestock Interventions and(or) Animal Ownership

The impacts of livestock interventions or animal ownership can be summarized in a qualitative manner that indicates whether the existing evidence suggests a positive, negative, or uncertain outcome on a variety of indicators (Table 5). Although most of the studies examined in this review have design limitations that weaken the inferences that can be drawn from them, the impacts of livestock interventions or ownership generally tend to be positive. Livestock interventions generally tend to increase production and consumption of ASF. However, as noted in Chapter 4, the impacts of increases in production on consumption are sometimes small and interventions that improve market outlets may even result in reduced consumption (Alderman, 1987, Nicholson et al., 1998). Impacts on overall dietary intake and nutritional status were also generally positive, although attribution of nutritional improvements to the livestock component is more difficult in the studies that integrated a number of production and educational components. In general, interventions targeting women and those with educational components generally show the clearest positive impact on nutritional status. Although our examination of arc elasticities indicates that increases in consumption of ASF are proportionally smaller than increases in production for many livestock-related interventions, an important question that remains largely unanswered is the extent to which the reported increase in ASF consumption was a direct effect of increased production or indirect effect of increased income.

Impacts on income and expenditure were also found to be positive, with a range from modest to large. The impact on women's (control over) income and women's time and workload appear to be site- and production-system specific. Introducing livestock production or intensifying current production systems may lead to an increase in women's workload, without any significant benefits in terms of income, but the literature suggests that this is not a general pattern. The existing evidence from the literature is inconclusive with regard to the impacts of livestock

Table 6. Summary of Relationships Between of Livestock Ownership and Various Outcome Indicators

Study Type	Outcome Indicator								
	Production	ASF Intake	Overall Dietary Intake	Nutritional Status	Income and(or) Expenditure	Caregiver Income	Caregiver Time and Workload	Maternal Laborforce Participation	Incidence of Zoonotic Disease
Intervention-related studies									
Aquaculture studies	0 to +	0 to +	NE	NE	+	- to +	NE	NE	NE
Dairy studies	+	- to +	+	NE	+	- to +	0 to +	NE	NE
Poultry studies	0 to +	+	+	+?	+	NE	NE	NE	NE
Integrated studies	+	+	+	+?	+	NE	NE	NE	NE
Non-intervention studies									
Cattle ownership studies	NE	NE	NE	++	NE	NE	NE	NE	NE
Dairy cow ownership studies	++	+	NE	0 to ++	++	NE	- to 0	NE	NE
Maternal labor studies	NE	NE	NE	NE	NE	NE	NE	- to 0?	NE
Zoonotic disease studies	NE	NE	NE	NE	NE	NE	NE	NE	?

0 = studies suggest no impact on outcome
- = studies suggest a negative impact on outcome (i.e., a decrease). Note that this does not always imply that this is an undesirable outcome.
+ = studies suggest a positive impact on outcome (i.e., an increase). Note that this does not always imply that this is a desirable outcome.
? = studies suggest uncertain impact on outcome
NE = Not examined by studies of this type

interventions or ownership on human disease incidence. It is worth noting that intervention studies on zoonotic infections or zooprophylaxis and zoopotentiation are absent from the literature. Moreover, it is quite possible that the promotion of animal husbandry in poor societies may lead to an increase in infectious diseases (and malaria in malaria endemic areas).

Implications for Livestock-related Development Activities

Although the available evidence is not as complete or convincing as many would like it to be, there are still a number of implications of the findings of this review with regard to future efforts to promote livestock production. First, taken as a whole, the existing evidence suggests that livestock production can have modest to moderate positive impacts on ASF production, ASF consumption, overall dietary intake, incomes, and nutritional status. At a minimum, the observed outcomes where reasonably adequate empirical evidence exists suggests that livestock interventions and ownership satisfy the "do no harm" criteria with regard to nutritional status, in a manner analogous to the general findings from the "cash crop" literature in the 1990s. This implies the promotion of livestock production with the objective of achieving other development goals often will be appropriate, because there appear to be no corresponding negative impacts on nutritional status. The one notable exception to this conclusion derives from our very limited preliminary knowledge of linkages between livestock production and zoonotic disease incidence. Second, as noted previously, the evidence suggests that interventions that more explicitly target women and integrate educational components may have more consistent positive effects on ASF intake, overall dietary intake, and nutritional status than those interventions that do not. Although it is beyond the scope of this document to review the effectiveness of various nutritional education programs, future livestock-related interventions can usefully consider inclusion of these efforts. Third, although the evidence is limited to two studies, interventions that primarily increase access to markets (or create new market outlets) may result in decreased household consumption of ASF and(or) changes in the control of income from the sales of livestock products. Careful attention to these possibilities in the design of future livestock-related interventions will help to prevent undesired and(or) unanticipated consequences of this type. Finally, greater attention should be given to appropriate monitoring and evaluation of livestock-related interventions. Monitoring and evaluation activities can be costly, methodologically challenging and time-consuming, and there is sometimes the perception that evaluation efforts will take resources away from activities that are "known" to be benefiting target beneficiaries—although empirical evidence is often lacking. Monitoring and evaluation, however, provide information that can be used help improve the effectiveness of interventions on the ground. In addition, when evaluation information is shared with other organizations, it will also help build a broader, better understanding about what characteristics of livestock interventions can make them more beneficial to their target audiences. In light of our limited current knowledge about the relationships between livestock production and zoonotic disease incidence, future livestock interventions should explicitly monitor project participants for possible negative health impacts.

Implications for Future Research

Future research activities related to livestock and nutritional outcomes must be undertaken with prior consideration of two key issues: priority research topics and study design issues. It is clear from the foregoing review that our knowledge of the relationships between livestock production and human health is at an early stage, and much more work is needed to understand essentially all of the relationships. Given the limited state of existing knowledge, how should research priorities be determined? There are at least two approaches that can be used to guide future research efforts. The first is to examine the existing evidence (as in Table 5), determine where relatively less is known, and focus future research efforts in these areas. By this approach, the priority research topics are the relationship between livestock interventions or ownership and caregiver income, caregiver work responsibilities, maternal labor force participation and human disease transmission. It is worth noting that for each of these areas, the potential for negative impacts on nutritional status—particularly for children—is likely to be larger than the potential for positive impacts. Thus, further research in these areas will also help to define more clearly the potential downsides to the promotion of livestock production, although the existing studies suggest that livestock production on balance will have positive impacts overall. Additional information on these potential negative effects may allow modification of interventions to minimize or eliminate them.

A second approach to defining research priorities is to assess the relationships likely to have the greatest potential for either positive or negative impacts, and to focus research attention on them. One possible example, although not given detailed attention in this report, is the role that complementary feeding with ASF can play during a developmental period often characterized by compromised nutritional status. Another way identify research priorities is consider where in the complex system generating nutritional outcomes are there opportunities to most effectively intervene to enhance the nutritional benefits of livestock or mitigate negative nutritional effects. These "high-leverage" points are currently typically identified through professional judgment alone, but preferably this process could be improved and made more reliable by applying various systems thinking and modeling tools. Systems thinking and modeling approaches are often criticized because of a perception that they require "too much—typically unavailable—data." In contrast, however, there is a body of thought that suggests that appropriately-specified system structures (i.e., hypothesized causal relationships based on existing knowledge and sometimes a degree of cautious speculation) can provide information about what relationships and parameters are most important to understanding behavior of key outcomes over time, and can clarify conceptualizations of the various interacting factors of importance (Sterman, 2000). Simulation models can be useful to identify priority information needs, even in the absence of complete data, because sensitivity analyses can be used to determine what information (e.g., parameter values) have the most importance for predicting outcomes of interest. Although little applied to the understanding of relationships between livestock and nutritional status to date, systems thinking and modeling approaches appear to have potential as a tool to assist in the identification of research priorities and the design of livestock-related interventions. Previous systems modeling work on agricultural "poverty traps" has indicated both the feasibility of this approach, the benefits to the cross-disciplinary conceptualization, and the importance of livestock to household welfare (Brown and Tsoi, 2005).

A second dimension of future research efforts concerns study design. As mentioned above, all of the studies reviewed have various methodological limitations that reduce—in some cases markedly—our ability to draw inferences from them. It was also noted in Chapters 1 and 4 that implementation of the "gold standard" of controlled experimentation to examine the relationships between livestock interventions or ownership is fraught with challenges, and this is borne out by the nature of the studies included in this review. Most future studies of these relationships, like previous ones, will be "comparative observational studies" in which "a key feature is the lack of planned or controlled intervention or allocation of people and treatments" (Hoagland et al., 1982). Thus, efforts should focus on improvement of designs for this type of study. It is well beyond the scope of this review to describe in detail the plethora of designs appropriate for various situations. However, Hoagland et al. suggest a number of approaches to strengthen observational studies, some of which mirror those that strengthen controlled experiments.

The recommendations include:

- Use of additional (background) information and statistical methods (e.g., econometrics, covariance analysis) to adjust for the effects of other variables on observed outcomes, including the decision to participate in a livestock project, if relevant;
- Stratification of treatment and control groups, application of appropriate weighting schemes for outcomes of interest, and comparison of weighted outcomes;
- Use of multiple control groups;
- Matching individuals or households in "treatment" groups with those in control groups to approximately equate background variables (Case-Control Method) and more recently developed econometric methods such as propensity score matching (Angrist and Hahn, 1999);
- Use of observational groups with different intensities of treatment, and assess whether the outcomes differ in a "rational manner" with the intensity of the treatment (Dose-Response Method);
- Use of simulation modeling—based on theory and previous empirical evidence—to estimate the outcomes that would occur in the absence of treatment, then compare this to the observed performance for relevant groups;
- Collection of multiple measurements of outcome indicators over time, not just "before and after";
- Explicit examination of differences, especially in baseline data, of characteristics of treatment and control groups;
- Careful consideration of whether other external factors that may explain the observed outcomes may have changed during the course of the "treatment". To the extent that probable outcomes and influencing factors can be identified in advance these can be identified as "monitoring assumptions" and explicitly tracked as a part of the study.
- In the case of intervention projects, the use of mixed research methods, e.g., operations research, process evaluation, QA approaches, diagnostic studies, "client" satisfaction surveys and planned capture of staff experiences can complement the "before and after" information about key outcomes. These activities and approaches can be included as a part of project monitoring and evaluation activities, to help establish the "plausible" impacts of the intervention, and improve implementation.

By identifying appropriate knowledge gaps and priorities and applying better study design, future research will be able to generate the information needed to identify opportunities for enhancing the potential for livestock keeping to provide nutritional benefits to the poor in developing countries, while minimizing associated health risks. In this review, livestock have generally been treated as a single, rather amorphous concept. It is evident that in fact the nutritional characteristics of different species and their production systems vary, particularly in terms of meat versus dairy products. Just as important is their nature in terms of flows of nutrients and income; a dairy goat provides a steady flow of milk; keeping guinea pigs generates a regular stream of small amounts of meat; bulls kept in pastoral systems, however, are likely to be slaughtered or sold only towards the end of their lifespan if they have not succumbed to disease or drought beforehand. It will therefore be important that as research efforts are strategically targeted to understand better the complex of key relationships between livestock keeping and nutritional well-being, a functional classification is developed that distinguishes the attributes and dynamics associated with each type of livestock or production system. The systems modeling approach described above would be particularly suited to this task. In this manner, nutrition research can lead to a practical guide for designing livestock-based interventions that can improve nutritional well-being of resource-poor populations among other development objectives, supported by a convincing body of scientific evidence.

APPENDIX A: TABLE A1. NUTRIENT COMPOSITION OF ANIMAL SOURCE FOODS IN KENYA AND INDONESIA (PER 100 G)

	energy	protein	fat	saturated fat	cholesterol	vitamin A	riboflavin	vitamin B12	calcium	iron	available iron	zinc	available zinc
	kcal	*g*	*g*	*g*	*mg*	*RE*	*mg*	*µg*	*mg*	*mg*	*mg*	*mg*	*mg*
Kenya													
Beef, High Fat, Cooked	381	24.1	30.9	14.9	87	0	0.14	1.8	4	1.6	0.304	3.9	2.145
Beef, Intestines and Stomach, Cooked	179	14.9	12.8	6	47	0	0.09	1.12	2	1	0.19	2.5	1.375
Beef, Lean, Cooked	269	24.9	18	8.4	75	0	0.15	1.87	4	1.7	0.323	4.1	2.255
Beef, Liver, Cooked	161	24.4	4.9	1.9	389	20357	3.6	110	7	6.8	1.292	6.1	3.355
Beef, Medium Fat, Cooked	323	24.9	24	11.4	82	0	0.15	1.87	4	1.7	0.323	4.1	2.255
Beef, Medium Fat, Raw	257	17.9	20	9.5	62	0	0.11	1.35	3	1.2	0.228	3	1.65
Chicken, Cooked	285	26.9	18.9	5.1	79	39	0.24	0.23	13	1.4	0.266	1.8	0.99
Chicken, Raw	200	18.8	13.2	3.6	55	27	0.17	0.16	9	1	0.19	1.3	0.715
Egg, Chicken	155	12.6	10.6	3.3	424	190	0.51	1.11	50	1.2	0.06	1.1	0.605
Fish, Raw	112	21.4	2.3	0.3	33	43	0.07	1.1	48	0.9	0.171	0.4	0.22
Goat Intestines and Stomach, Cooked	135	12.5	9	4.2	38	0	0.08	0.94	2	0.9	0.171	2.1	1.155
Goat Intestines and Stomach, Raw	121	11.2	8.1	3.8	34	0	0.07	0.84	2	0.8	0.152	1.8	0.99
Goat, Cooked	269	24.9	18	8.4	75	0	0.15	1.87	4	1.7	0.323	4.1	2.255
Goat, Raw	188	17.4	12.6	5.9	53	0	0.11	1.31	3	1.2	0.228	2.9	1.595
Milk, Cow, Fluid, Non-Fortified	51	3.3	2.1	1.3	8	28	0.16	0.39	119	0.1	0.005	0.4	0.2
Milk, Cow, Pwd, Nonfat	368	35.7	2.1	1.1	21	11	1.47	3.99	1292	0	0	4.2	2.1
Milk, Cow, Pwd, Whole	488	23.7	28.9	17.8	104	407	1.26	2.96	851	0.7	0.035	3	1.5
Milk, Cow, Uht	66	3.2	3.9	2.4	14	55	0.17	0.4	115	0.1	0.005	0.4	0.2
Milk, Cow, Whole	66	3.2	3.9	2.4	14	55	0.17	0.4	115	0.1	0.005	0.4	0.2
Milk, Goat	69	3.6	4.1	2.7	11	56	0.14	0.07	134	0.1	0.005	0.3	0.15
Mutton, Cooked	269	24.9	18	8.4	75	0	0.15	1.87	4	1.7	0.323	4.1	2.255
Mutton, High Fat, Cooked	381	24.1	30.9	14.9	87	0	0.14	1.8	4	1.6	0.304	3.9	2.145
Mutton, Medium, Cooked	269	24.9	18	8.4	75	0	0.15	1.87	4	1.7	0.323	4.1	2.255
Pork, High Fat, Cooked	369	19.7	31.2	10.8	83	1	0.25	1.73	32	1.3	0.247	2.5	1.375
Pork, Intestines and Stomach, Cooked	285	8.8	27.5	10.6	50	1	0.11	0.25	8	0.4	0.076	0.9	0.495
Pork, Lean, Cooked	372	27.6	28.2	10.5	101	2	0.33	0.77	25	1.1	0.209	2.9	1.595
Pork, Medium Fat, Cooked	537	19.6	50.2	19.3	101	1	0.23	0.55	18	0.8	0.152	2.1	1.155
Rabbit, Raw	132	19.7	5.3	2.2	49	0	0.11	1.47	4	1.3	0.247	3.2	1.76
Termite	369	19.7	31.2	10.8	83	1	0.25	1.73	32	1.3	0.247	2.5	1.375

	energy	protein	fat	saturated fat	cholesterol	vitamin A	riboflavin	vitamin B12	calcium	iron	available iron	zinc	available zinc
	kcal	*g*	*g*	*g*	*mg*	*RE*	*mg*	*µg*	*mg*	*mg*	*mg*	*mg*	*mg*
Indonesia													
Egg, Chicken	155	12.6	10.6	3.3	424	190	0.51	1.11	50	1.2	0.06	1.1	0.605
Egg, Chicken, White Of	50	10.5	0	0	0	0	0.45	0.2	6	0	0	0	0
Egg, Chicken, Yolk	278	19.2	20.7	5.6	1326	810	0.6	8.1	96	5.9	0.295	2.1	1.155
Egg, Duck	185	12.8	13.8	3.7	884	540	0.4	5.4	64	3.9	0.195	1.4	0.77
Egg, Duck, Manila	185	12.8	13.8	3.7	884	540	0.4	5.4	64	3.9	0.195	1.4	0.77
Egg, Duck, White Of	50	10.5	0	0	0	0	0.45	0.2	6	0	0	0	0
Egg, Duck, Yolk	563	25.7	49.5	21	1824	1284	0.8	10.81	130	7.8	0.39	2.8	1.54
Egg, Pigeon	185	12.8	13.8	3.7	884	540	0.4	5.4	64	3.9	0.195	1.4	0.77
Egg, Quail	185	12.8	13.8	3.7	884	540	0.4	5.4	64	3.9	0.195	1.4	0.77
Egg, Rice Field Bird	185	12.8	13.8	3.7	884	540	0.4	5.4	64	3.9	0.195	1.4	0.77
Egg, Sea Turtle	155	12.6	10.6	3.3	424	190	0.51	1.11	50	1.2	0.06	1.1	0.605
Fish Egg	163	19.8	8.4	2.1	463	297	0.25	3.39	62	2.6	0.414	1	0.55
Milk, Cow, Condensed, Sweetened	320	7.8	8.7	5.3	33	62	0.38	0.18	300	0.2	0.01	0.9	0.45
Milk, Cow, Powdered, Skim	368	35.7	2.1	1.1	21	11	1.47	3.99	1292	0	0	4.2	2.1
Milk, Cow, Powdered, Sour	504	25.6	28.6	17.3	109	203	1.2	0.6	981	0.8	0.04	3	1.5
Milk, Cow, Skim	35	3.4	0.2	0.1	2	1	0.14	0.38	123	0	0	0.4	0.2
Milk, Cow, Whole	66	3.2	3.9	2.4	14	55	0.17	0.4	115	0.1	0.005	0.4	0.2
Milk, Cow, Whole, Uht	66	3.2	3.9	2.4	14	55	0.17	0.4	115	0.1	0.005	0.4	0.2
Milk, Goat	69	3.6	4.1	2.7	11	56	0.14	0.07	134	0.1	0.005	0.3	0.15
Omelette, Duck Egg	271	12.8	23.8	12.4	884	540	0.4	5.4	64	3.9	0.195	1.4	0.77
Ant, Flying White	274	18.2	21.5	7.5	75	1	0.23	1.56	90	2.5	0.475	8.4	4.62
Bat, Cave, Meat	269	24.9	18	8.4	75	0	0.15	1.87	4	1.7	0.323	4.1	2.255
Bee, Larvae	285	15	21	9.2	71	1	1.17	1.47	18	3.1	0.589	4.9	2.695
Beef	269	24.9	18	8.4	75	0	0.15	1.87	4	1.7	0.323	4.1	2.255
Beef Or Pork Skin, Raw	381	24.1	30.9	14.9	87	0	0.14	1.8	4	1.6	0.304	3.9	2.145
Beef, Blood, Coagulated	145	25.1	4.2	1.4	347	0	0.3	5.02	12	39.4	7.486	2.8	1.54
Beef, Corned	269	24.9	18	8.4	75	0	0.15	1.87	5	1.7	0.323	4.1	2.255
Beef, Intestines	94	14.1	3.8	1.6	35	0	0.08	1.05	3	1	0.19	2.3	1.265
Beef, Liver	161	24.4	4.9	1.9	389	20357	3.6	110	7	6.8	1.292	6.1	3.355
Beef, Spleen	145	25.1	4.2	1.4	347	0	0.3	5.02	12	39.4	7.486	2.8	1.54
Bird, Gizzard	166	29	4.7	1.7	69	0	0.17	2.17	5	2	0.38	4.7	2.585

	energy	protein	fat	saturated fat	cholesterol	vitamin A	riboflavin	vitamin B12	calcium	iron	available iron	zinc	available zinc
	kcal	*g*	*g*	*g*	*mg*	*RE*	*mg*	*µg*	*mg*	*mg*	*mg*	*mg*	*mg*
Bird, Head	148	14	9.8	2.7	41	20	0.12	0.12	7	0.7	0.133	0.9	0.495
Bird, Liver	157	24.4	5.5	1.8	631	11325	2.7	56	14	8.5	1.615	4.3	2.365
Bird, Meat	337	19	28.4	9.7	84	63	0.27	0.3	11	2.7	0.513	1.9	1.045
Brain	160	11.1	12.5	2.9	2054	0	0.17	8.6	9	2.2	0.418	1.3	0.715
Chicken	285	26.9	18.9	5.1	79	39	0.24	0.23	13	1.4	0.266	1.8	0.99
Chicken, Blood, Coagulated	145	25.1	4.2	1.4	347	0	0.3	5.02	12	39.4	7.486	2.8	1.54
Chicken, Brains	160	11.1	12.5	2.9	2054	0	0.17	8.6	9	2.2	0.418	1.3	0.715
Chicken, Broth	8	0.5	0.3	0.1	0	0	0.01	0.03	2	0.1	0.019	0	0
Chicken, Gizzard	166	29	4.7	1.7	69	0	0.17	2.17	5	2	0.38	4.7	2.585
Chicken, Head	148	14	9.8	2.7	41	20	0.12	0.12	7	0.7	0.133	0.9	0.495
Chicken, Heart	166	29	4.7	1.7	69	0	0.17	2.17	5	2	0.38	4.7	2.585
Chicken, Innards	94	14.1	3.8	1.6	35	0	0.08	1.05	3	1	0.19	2.3	1.265
Chicken, Intestines	94	14.1	3.8	1.6	35	0	0.08	1.05	3	1	0.19	2.3	1.265
Chicken, Leg	202	11.4	17	5.8	50	38	0.16	0.18	7	1.6	0.304	1.1	0.605
Chicken, Liver	157	24.4	5.5	1.8	631	11325	2.7	56	14	8.5	1.615	4.3	2.365
Chicken, Meat	285	26.9	18.9	5.1	79	39	0.24	0.23	13	1.4	0.266	1.8	0.99
Chicken, Spleen	145	25.1	4.2	1.4	347	0	0.3	5.02	12	39.4	7.486	2.8	1.54
Chicken, Thigh	214	20.2	14.2	3.8	59	29	0.18	0.17	10	1.1	0.209	1.4	0.77
Chicken, Wing	148	14	9.8	2.7	41	20	0.12	0.12	7	0.7	0.133	0.9	0.495
Cricket	274	18.2	21.5	7.5	75	1	0.23	1.56	90	2.5	0.475	8.4	4.62
Duck, Blood, Coagulated	116	20.1	3.4	1.1	278	0	0.24	4.02	10	31.5	5.985	2.2	1.21
Duck, Gizzard	166	29	4.7	1.7	69	0	0.17	2.17	5	2	0.38	4.7	2.585
Duck, Head	175	9.9	14.8	5	44	33	0.14	0.16	6	1.4	0.266	1	0.55
Duck, Heart	166	29	4.7	1.7	69	0	0.17	2.17	5	2	0.38	4.7	2.585
Duck, Intestines	94	14.1	3.8	1.6	35	0	0.08	1.05	3	1	0.19	2.3	1.265
Duck, Liver	157	24.4	5.5	1.8	631	11325	2.7	56	14	8.5	1.615	4.3	2.365
Duck, Liver W/Spices	157	24.4	5.5	1.8	631	11325	2.7	56	14	8.5	1.615	4.3	2.365
Duck, Manila, Gizzard	166	29	4.7	1.7	69	0	0.17	2.17	5	2	0.38	4.7	2.585
Duck, Manila, Head	175	9.9	14.8	5	44	33	0.14	0.16	6	1.4	0.266	1	0.55
Duck, Manila, Heart	166	29	4.7	1.7	69	0	0.17	2.17	5	2	0.38	4.7	2.585
Duck, Manila, Innards	94	14.1	3.8	1.6	35	0	0.08	1.05	3	1	0.19	2.3	1.265
Duck, Manila, Intestines	94	14.1	3.8	1.6	35	0	0.08	1.05	3	1	0.19	2.3	1.265
Duck, Manila, Leg	337	19	28.4	9.7	84	63	0.27	0.3	11	2.7	0.513	1.9	1.045

	energy	protein	fat	saturated fat	cholesterol	vitamin A	riboflavin	vitamin B12	calcium	iron	available iron	zinc	available zinc
	kcal	*g*	*g*	*g*	*mg*	*RE*	*mg*	*µg*	*mg*	*mg*	*mg*	*mg*	*mg*
Duck, Manila, Liver	157	24.4	5.5	1.8	631	11325	2.7	56	14	8.5	1.615	4.3	2.365
Duck, Manila, Meat	337	19	28.4	9.7	84	63	0.27	0.3	11	2.7	0.513	1.9	1.045
Duck, Manila, Wing	175	9.9	14.8	5	44	33	0.14	0.16	6	1.4	0.266	1	0.55
Duck, Meat	337	19	28.4	9.7	84	63	0.27	0.3	11	2.7	0.513	1.9	1.045
Duck, Skin	337	19	28.4	9.7	84	63	0.27	0.3	11	2.7	0.513	1.9	1.045
Duck, Thigh	253	14.3	21.3	7.3	63	47	0.2	0.23	8	2	0.38	1.4	0.77
Duck, Wing	175	9.9	14.8	5	44	33	0.14	0.16	6	1.4	0.266	1	0.55
Frog	98	20.1	1.4	0.5	46	0	0.19	1.31	11	1.6	0.304	1.9	1.045
Goat, Blood, Coagulated	116	20.1	3.4	1.1	278	0	0.24	4.02	10	31.5	5.985	2.2	1.21
Goat, Feet	70	6.5	4.7	2.2	20	0	0.04	0.49	1	0.4	0.076	1.1	0.605
Goat, Meat	269	24.9	18	8.4	75	0	0.15	1.87	4	1.7	0.323	4.1	2.255
Heron, Meat	337	19	28.4	9.7	84	63	0.27	0.3	11	2.7	0.513	1.9	1.045
Insect, Flying	274	18.2	21.5	7.5	75	1	0.23	1.56	90	2.5	0.475	8.4	4.62
Insect, Uthi-Uthi	274	18.2	21.5	7.5	75	1	0.23	1.56	90	2.5	0.475	8.4	4.62
Lizard, Monitor, Liver	161	24.4	4.9	1.9	389	20357	3.6	110	7	6.8	1.292	6.1	3.355
Lizard, Monitor, Meat	131	26.8	1.8	0.6	61	0	0.25	1.75	15	2.1	0.399	2.5	1.375
Mutton, Meat	269	24.9	18	8.4	75	0	0.15	1.87	4	1.7	0.323	4.1	2.255
Pigeon, Gizzard	166	29	4.7	1.7	69	0	0.17	2.17	5	2	0.38	4.7	2.585
Pigeon, Heart	166	29	4.7	1.7	69	0	0.17	2.17	5	2	0.38	4.7	2.585
Pigeon, Liver	157	24.4	5.5	1.8	631	11325	2.7	56	14	8.5	1.615	4.3	2.365
Pigeon, Meat	208	28.1	9.7	2.8	82	0	0.18	0.35	26	1.8	0.342	3	1.65
Quail, Meat	208	28.1	9.7	2.8	82	0	0.18	0.35	26	1.8	0.342	3	1.65
Squirrel, Meat	166	29	4.7	1.7	69	0	0.17	2.17	5	2	0.38	4.7	2.585
Tripe	83	14.5	2.4	0.9	35	0	0.09	1.09	3	1	0.19	2.4	1.32
Water Buffalo, Blood, Coagulated	116	20.1	3.4	1.1	278	0	0.24	4.02	10	31.5	5.985	2.2	1.21
Water Buffalo, Liver	161	24.4	4.9	1.9	389	20357	3.6	110	7	6.8	1.292	6.1	3.355
Water Buffalo, Meat	131	26.8	1.8	0.6	61	0	0.25	1.75	15	2.1	0.399	2.5	1.375
Clam	103	14.3	2.7	0.5	34	32	0.23	13.26	20	4	0.76	1.6	0.88
Crab, Fresh Water	90	16.9	2	0.4	153	137	0.02	1.3	30	2.2	0.418	1.4	0.77
Crab, Sea	87	16.5	1.3	0.3	145	46	0.07	3.93	29	3.2	0.608	5.1	2.805
Crab, Small	53	11.4	0.5	0.1	28	7	0.04	0.53	7	0.3	0.057	0.3	0.165
Eel, River	189	19	12	2.4	129	909	0.04	2.31	21	0.5	0.095	1.7	0.935
Eel, Swamp, Raw	112	21.4	2.3	0.3	33	43	0.07	1.1	48	0.9	0.171	0.4	0.22

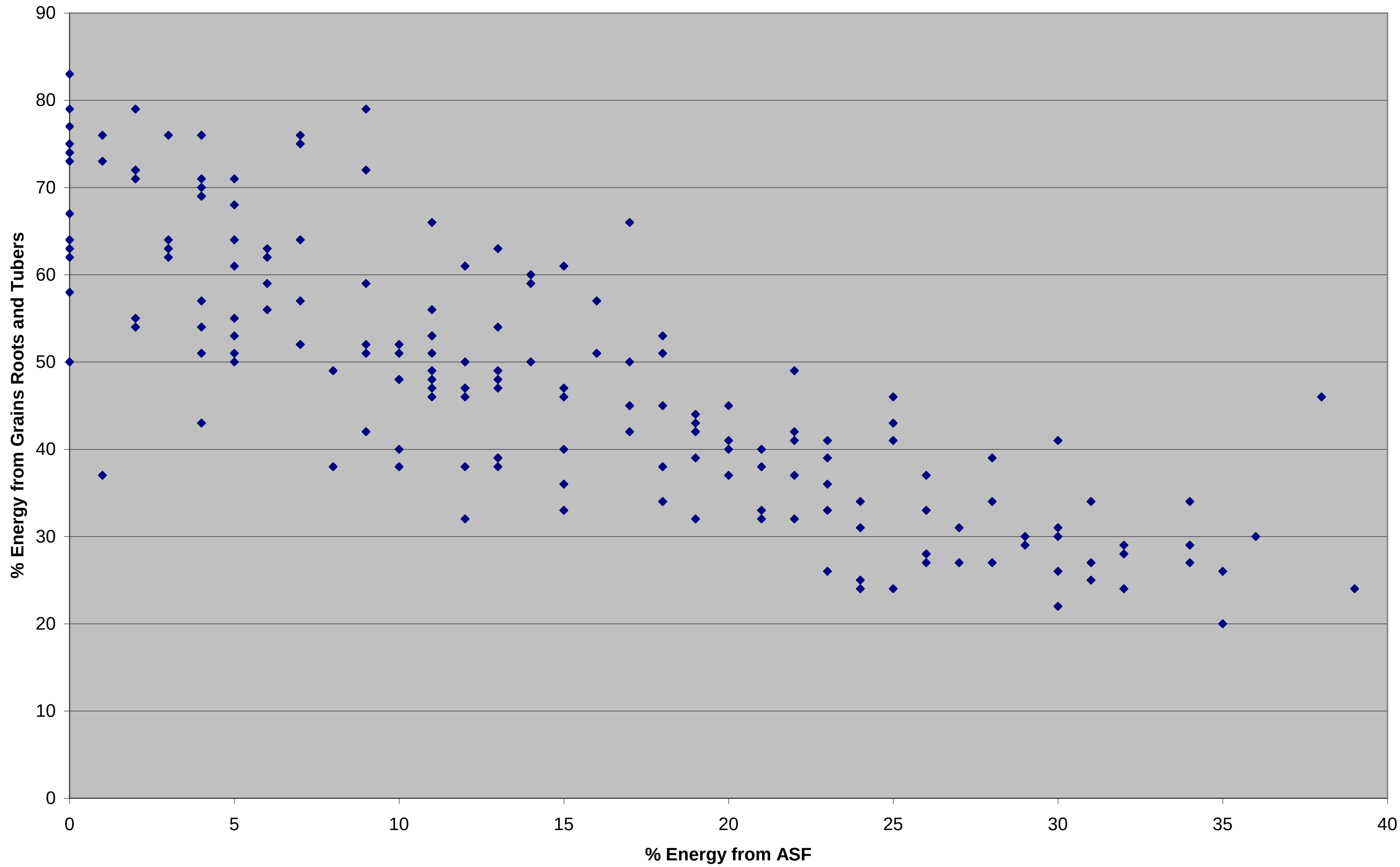
	energy	protein	fat	saturated fat	cholesterol	vitamin A	riboflavin	vitamin B12	calcium	iron	available iron	zinc	available zinc
	kcal	*g*	*g*	*g*	*mg*	*RE*	*mg*	*µg*	*mg*	*mg*	*mg*	*mg*	*mg*
Fish Paste, Red, Fermented	105	18.5	2.9	0.7	72	15	0.07	2.9	12	0.4	0.076	0.6	0.33
Fish, Anchovy, Dried (Teri Nasi)	335	58.6	9.4	2	57	0	0.27	12	1700	2.5	0.475	5.2	2.6
Fish, Anchovy, Dried (Teri Tawar)	335	58.6	9.4	2	57	0	0.27	12	1700	2.5	0.475	5.2	2.6
Fish, Anchovy, Dried, Salted	335	58.6	9.4	2	57	0	0.27	12	1703	2.5	0.475	5.2	2.6
Fish, Anchovy, Flour (Bubuk)	375	65.6	10.5	2.2	64	0	0.3	13.44	1904	2.8	0.532	5.8	2.9
Fish, Anchovy, Flour (Tepung)	375	65.6	10.5	2.2	64	0	0.3	13.44	1904	2.8	0.532	5.8	2.9
Fish, Anchovy, Fresh (Teri)	112	21.4	2.3	0.3	33	43	0.07	1.1	48	0.9	0.171	0.4	0.22
Fish, Anchovy, Salted (Bilis)	245	53.1	2	0.4	128	0	0.09	2.44	36	1.1	0.209	1.4	0.77
Fish, Anchovy, Salted (Teri)	335	58.6	9.4	2	57	0	0.27	12	1702	2.5	0.475	5.2	2.6
Fish, Barracuda	84	18.2	0.7	0.2	44	11	0.06	0.84	11	0.4	0.076	0.5	0.275
Fish, Barracuda, Salted	84	18.2	0.7	0.2	44	11	0.06	0.84	13	0.4	0.076	0.5	0.275
Fish, Bedhek	58	8.1	1.5	0.3	19	18	0.13	7.51	11	2.3	0.437	0.9	0.495
Fish, Bojor, Liver	157	24.4	5.5	1.8	631	11325	2.7	56	14	8.5	1.615	4.3	2.365
Fish, Boso, Raw	112	21.4	2.3	0.3	33	43	0.07	1.1	48	0.9	0.171	0.4	0.22
Fish, Cardinal, Salted	84	18.2	0.7	0.2	44	11	0.06	0.84	13	0.4	0.076	0.5	0.275
Fish, Carp, Fresh	130	18.3	5.8	1.1	67	7	0.06	1.18	42	1.3	0.247	1.5	0.825
Fish, Catfish (Lele Dumbo)	159	16.3	10.4	3	40	27	0.14	8.8	26	0.8	0.152	0.4	0.22
Fish, Catfish (Lele)	84	14.8	2.3	0.6	58	12	0.06	2.32	9	0.3	0.057	0.5	0.275
Fish, Catfish And Other Freshwater Fish	159	16.3	10.4	3	40	27	0.14	8.8	26	0.8	0.152	0.4	0.22
Fish, Catfish, Egg	163	19.8	8.4	2.1	463	297	0.25	3.39	62	2.6	0.414	1	0.55
Fish, Crevalle, Dried	162	22.9	7.2	1.4	84	9	0.07	1.47	52	1.6	0.304	1.9	1.045
Fish, Crevalle, Fresh	112	21.4	2.3	0.3	33	43	0.07	1.1	48	0.9	0.171	0.4	0.22
Fish, Crevalle, Salted	162	22.9	7.2	1.4	84	9	0.07	1.47	55	1.6	0.304	1.9	1.045
Fish, Crevalle, Steam/Salted	140	26.7	2.9	0.4	41	54	0.09	1.37	60	1.1	0.209	0.5	0.275
Fish, Dares, Raw	112	21.4	2.3	0.3	33	43	0.07	1.1	48	0.9	0.171	0.4	0.22
Fish, Dried, Salted	306	66.4	2.5	0.5	160	0	0.11	3.05	44	1.4	0.266	1.7	0.935
Fish, Fighting, Raw	84	14.8	2.3	0.6	58	12	0.06	2.32	9	0.3	0.057	0.5	0.275
Fish, Flying, Salted	84	18.2	0.7	0.2	44	11	0.06	0.84	13	0.4	0.076	0.5	0.275
Fish, Fresh	98	18.1	2.4	0.5	45	28	0.07	1.71	28	0.6	0.114	0.4	0.22
Fish, Gouramy, Dried	250	29.5	13.8	1.8	170	80	0.43	10.73	660	3.5	0.665	3.6	1.8
Fish, Gouramy, Fresh	130	18.3	5.8	1.1	67	7	0.06	1.18	42	1.3	0.247	1.5	0.825
Fish, Gray Mullet	84	14.8	2.3	0.6	58	12	0.06	2.32	9	0.3	0.057	0.5	0.275
Fish, Gray Mullet, Dried, Salted	245	53.1	2	0.4	128	0	0.09	2.44	36	1.1	0.209	1.4	0.77

	energy	protein	fat	saturated fat	cholesterol	vitamin A	riboflavin	vitamin B12	calcium	iron	available iron	zinc	available zinc
	kcal	*g*	*g*	*g*	*mg*	*RE*	*mg*	*µg*	*mg*	*mg*	*mg*	*mg*	*mg*
Fish, Herring	53	11.4	0.5	0.1	28	7	0.04	0.53	7	0.3	0.057	0.3	0.165
Fish, Herring, Salted	245	53.1	2	0.4	128	0	0.09	2.44	36	1.1	0.209	1.4	0.77
Fish, Herring, Steam/Salted	112	21.4	2.3	0.3	33	43	0.07	1.1	50	0.9	0.171	0.4	0.22
Fish, Jempol	140	26.7	2.9	0.4	41	54	0.09	1.37	60	1.1	0.209	0.5	0.275
Fish, Kating, Egg	163	19.8	8.4	2.1	463	297	0.25	3.39	62	2.6	0.414	1	0.55
Fish, Lawes	84	14.8	2.3	0.6	58	12	0.06	2.32	9	0.3	0.057	0.5	0.275
Fish, Lukas	140	26.7	2.9	0.4	41	54	0.09	1.37	60	1.1	0.209	0.5	0.275
Fish, Luthok	159	16.3	10.4	3	40	27	0.14	8.8	26	0.8	0.152	0.4	0.22
Fish, Luthok, Egg, Raw	163	19.8	8.4	2.1	463	297	0.25	3.39	62	2.6	0.414	1	0.55
Fish, Mackerel	112	21.4	2.3	0.3	33	43	0.07	1.1	48	0.9	0.171	0.4	0.22
Fish, Mackerel, King	112	21.4	2.3	0.3	33	43	0.07	1.1	48	0.9	0.171	0.4	0.22
Fish, Mackerel, Salted	112	21.4	2.3	0.3	33	43	0.07	1.1	50	0.9	0.171	0.4	0.22
Fish, Mackerel, Steam/Salted (Banjar)	112	21.4	2.3	0.3	33	43	0.07	1.1	50	0.9	0.171	0.4	0.22
Fish, Mackerel, Steam/Salted (Kembung)	140	26.7	2.9	0.4	41	54	0.09	1.37	62	1.1	0.209	0.5	0.275
Fish, Mackerel, Wet Salted (A)	112	21.4	2.3	0.3	33	43	0.07	1.1	50	0.9	0.171	0.4	0.22
Fish, Mackerel, Wet Salted (B)	112	21.4	2.3	0.3	33	43	0.07	1.1	50	0.9	0.171	0.4	0.22
Fish, Milk-Fish	84	14.8	2.3	0.6	58	12	0.06	2.32	9	0.3	0.057	0.5	0.275
Fish, Moto Botor	112	21.4	2.3	0.3	33	43	0.07	1.1	48	0.9	0.171	0.4	0.22
Fish, Muntreng, Fresh	112	21.4	2.3	0.3	33	43	0.07	1.1	48	0.9	0.171	0.4	0.22
Fish, Pe	53	9.3	1.5	0.4	36	8	0.04	1.45	6	0.2	0.038	0.3	0.165
Fish, Pepetek	84	14.8	2.3	0.6	58	12	0.06	2.32	9	0.3	0.057	0.5	0.275
Fish, Pepetek, Salted	84	14.8	2.3	0.6	58	12	0.06	2.32	11	0.3	0.057	0.5	0.275
Fish, Perch	84	18.2	0.7	0.2	44	11	0.06	0.84	11	0.4	0.076	0.5	0.275
Fish, Perch, Egg, Raw	163	19.8	8.4	2.1	463	297	0.25	3.39	62	2.6	0.414	1	0.55
Fish, Pomfret, Black	84	18.2	0.7	0.2	44	11	0.06	0.84	11	0.4	0.076	0.5	0.275
Fish, Ray	84	18.2	0.7	0.2	44	11	0.06	0.84	11	0.4	0.076	0.5	0.275
Fish, Red Snapper	105	22.8	0.9	0.2	55	14	0.08	1.05	14	0.5	0.095	0.6	0.33
Fish, Salem, Fresh	84	18.2	0.7	0.2	44	11	0.06	0.84	11	0.4	0.076	0.5	0.275
Fish, Sardines	112	21.4	2.3	0.3	33	43	0.07	1.1	48	0.9	0.171	0.4	0.22
Fish, Sardines, Canned In Oil	341	24.6	26.5	3.7	142	67	0.36	8.94	550	2.9	0.551	3	1.5
Fish, Sasi, Fresh	70	13.4	1.5	0.2	21	27	0.05	0.69	30	0.6	0.114	0.3	0.165
Fish, Scad	82	17.8	0.7	0.2	43	11	0.06	0.82	11	0.4	0.076	0.5	0.275
Fish, Scad, Steam/Salted (Benggol)	105	22.8	0.9	0.2	55	14	0.08	1.05	17	0.5	0.095	0.6	0.33

	energy	protein	fat	saturated fat	cholesterol	vitamin A	riboflavin	vitamin B12	calcium	iron	available iron	zinc	available zinc
	kcal	*g*	*g*	*g*	*mg*	*RE*	*mg*	*μg*	*mg*	*mg*	*mg*	*mg*	*mg*
Fish, Scad, Steam/Salted (Layang)	105	22.8	0.9	0.2	55	14	0.08	1.05	17	0.5	0.095	0.6	0.33
Fish, Scad, Steam/Salted, Fried	277	22.8	20.9	17.5	55	14	0.08	1.05	17	0.5	0.095	0.6	0.33
Fish, Sea Perch	84	18.2	0.7	0.2	44	11	0.06	0.84	11	0.4	0.076	0.5	0.275
Fish, Sea, Salted	84	18.2	0.7	0.2	44	11	0.06	0.84	13	0.4	0.076	0.5	0.275
Fish, Shark	140	26.7	2.9	0.4	41	54	0.09	1.37	60	1.1	0.209	0.5	0.275
Fish, Smelt/Whiting, Fresh	84	18.2	0.7	0.2	44	11	0.06	0.84	11	0.4	0.076	0.5	0.275
Fish, Snakehead, Dried	245	53.1	2	0.4	128	0	0.09	2.44	33	1.1	0.209	1.4	0.77
Fish, Snakehead, Egg	163	19.8	8.4	2.1	463	297	0.25	3.39	62	2.6	0.414	1	0.55
Fish, Snakehead, Fresh	84	18.2	0.7	0.2	44	11	0.06	0.84	11	0.4	0.076	0.5	0.275
Fish, Snakehead, Salted	245	53.1	2	0.4	128	0	0.09	2.44	36	1.1	0.209	1.4	0.77
Fish, Spade, Raw	84	14.8	2.3	0.6	58	12	0.06	2.32	9	0.3	0.057	0.5	0.275
Fish, Sprat, Salted	159	16.3	10.4	3	40	27	0.14	8.8	28	0.8	0.152	0.4	0.22
Fish, Surung	84	18.2	0.7	0.2	44	11	0.06	0.84	11	0.4	0.076	0.5	0.275
Fish, Tawes/ Bader	159	16.3	10.4	3	40	27	0.14	8.8	26	0.8	0.152	0.4	0.22
Fish, Terongan	112	21.4	2.3	0.3	33	43	0.07	1.1	48	0.9	0.171	0.4	0.22
Fish, Terongan, Salted	245	53.1	2	0.4	128	0	0.09	2.44	36	1.1	0.209	1.4	0.77
Fish, Threadfin, Fresh	112	21.4	2.3	0.3	33	43	0.07	1.1	48	0.9	0.171	0.4	0.22
Fish, Tilapia, Dried	335	58.6	9.4	2	57	0	0.27	12	1700	2.5	0.475	5.2	2.6
Fish, Tilapia, Fresh	84	18.2	0.7	0.2	44	11	0.06	0.84	11	0.4	0.076	0.5	0.275
Fish, Tuna	111	24	1	0.2	46	16	0.05	2.39	17	0.7	0.133	0.6	0.33
Fish, Tuna, Steam/Salted	111	24	1	0.2	46	16	0.05	2.39	19	0.7	0.133	0.6	0.33
Fish, Wader	84	14.8	2.3	0.6	58	12	0.06	2.32	9	0.3	0.057	0.5	0.275
Fish, Wader, Salted	245	53.1	2	0.4	128	0	0.09	2.44	36	1.1	0.209	1.4	0.77
Fish, Wedok	159	16.3	10.4	3	40	27	0.14	8.8	26	0.8	0.152	0.4	0.22
Fish, Wedok, Dried	268	46.9	7.5	1.6	46	0	0.22	9.6	1360	2	0.38	4.2	2.1
Shrimp, Dried	306	66.4	2.5	0.5	160	0	0.11	3.05	41	1.4	0.266	1.7	0.935
Shrimp, Fresh	79	16.7	0.9	0.2	156	51	0.02	1.19	31	2.5	0.475	1.3	0.715
Shrimp, Small, Dried	306	66.4	2.5	0.5	160	0	0.11	3.05	41	1.4	0.266	1.7	0.935
Shrimp, Small, Fresh	79	16.7	0.9	0.2	156	51	0.02	1.19	31	2.5	0.475	1.3	0.715
Squid, Fresh	147	25	2.2	0.6	373	8	0.66	2.08	51	1.1	0.209	2.5	1.375
Butter	710	0.2	80.6	50.1	207	749	0.01	0.03	6	0.1	0.013	0	0
Cod Liver Oil	900	0	99.8	29.8	85	0	0	0	0	0	0	0	0
Beef Fat	902	0	100	49.8	109	0	0	0	0	0	0	0	0

	energy	protein	fat	saturated fat	cholesterol	vitamin A	riboflavin	vitamin B12	calcium	iron	available iron	zinc	available zinc
	kcal	*g*	*g*	*g*	*mg*	*RE*	*mg*	*µg*	*mg*	*mg*	*mg*	*mg*	*mg*
Chicken Fat	900	0	99.8	29.8	85	0	0	0	0	0	0	0	0
Water Buffalo Fat	857	0	95	47.3	104	0	0	0	0	0	0	0	0

Source: (University of California, 1996)



Appendix Figure 1. Percentage of Dietary Energy from Grains, Roots and Tubers and ASF, 2000-2002 (Source: FAO data)

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