3 The role of livestock and livestock diversity in sustainable diets

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Introduction

Sustainability is a complex and sometimes contested concept. While the overall concept is widely accepted and used, a clear definition is still problematic as different stakeholders – and stakeholders at different levels – have different interpretations. The Johannesburg Declaration on Sustainable Development states that there are three fundamental 'pillars' to sustainable development: environmental protection, economic growth and social equity, both in an inter- and intra-generational equity perspective. However, the 'three-pillars' model is imperfect because it is based on the assumption that trade-offs can be made between the environmental, social and economic dimensions of sustainability.

Growing demands for ecosystem services, particularly for food, water, timber, fibre and fuel, were the direct or indirect drivers of ecosystem changes. The Millennium Ecosystem Assessment (MEA, 2005a,b) estimated that human activities have resulted in approximately 60 per cent of the ecosystem services examined being degraded or used unsustainably. UNEP (2010) states that 'Agriculture and food consumption are identified as one of the most important drivers of environmental pressures, especially habitat change, climate change, water use and toxic emissions'. They further confirm FAO's (2006a) assessment of the livestock sector's environmental impact, due to the high trophic level of livestock in the food web and the related high land use.

Although the increased utilization of the provisioning services contributed substantially to net gains in human well-being and economic development, the global community seems now to have reached a point where the loss of some of the supporting, regulating and cultural ecosystem services appears to exceed 'planetary boundaries' and increase the vulnerability of resource supply systems (Rockström et al., 2009; McKinsey Global Institute, 2011). Food systems, from production over-processing to consumption, are an obvious area of vulnerability.

Several recent studies identified food production and consumption patterns as key factor for achieving sustainability (UNEP, 2010; Foresight, 2011; Grethe et al., 2011; McKinsey Global Institute, 2011; UNEP, 2011; Westhoek et al., 2011). Heller and Keoleian (2003) stated that 'A sustainable food system must be founded on a sustainable diet'. In 2010, FAO experts agreed on a general concept for sustainable diets being 'those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources.' With this definition, biodiversity is linked with human diets and with the diversity of livestock and livestock systems. However, trade-offs between the different pillars of sustainability, and temporal and spatial dimensions, are not addressed (Hoffmann, 2011b).

FAO (2011a) has started to develop a method for sustainability assessments of food and agriculture systems. Main criteria are environmental integrity (energy, climate, air, water, soil, material cycles, waste and biodiversity), economic resilience (strategic management, operating profit, vulnerability, local economy and decent livelihood), social well-being (human rights, equity, occupational health and safety, capacity building, food and nutrition security, product quality) and good governance (participation, accountability, rule of law, fairness and evaluation). This chapter addresses mainly environmental aspects of sustainable diets but touches also briefly on social and economic aspects. It describes the links between human diets, expected changes in lifestyle, livestock sector trends and their combined impact on animal genetic resources. Specifically, the focus is on the genetic resources of domesticated avian and mammalian species that contribute to food production and agriculture.

Products and services provided by livestock

Livestock are used by humans to provide a wide range of products and services. Foods derived from animals are an important source of nutrients (Givens, 2010) that provide a critical supplement and diversity to staple plant-based diets (Murphey and Allen, 2003; Randolph et al., 2007). However, there are other reasons for keeping livestock, which include providing manure, fibre for clothes and resources for temporary and permanent shelter, producing power, and serving as financial instruments and enhancing social status. This range of products and services supporting livelihoods – especially of the poor – is a key feature of livestock. Until recently, a large proportion of livestock in developing countries was not kept solely for food. Due to an ongoing trend away from backyard and smallholder livestock production to more intensive and larger-scale systems (FAO, 2010b), many purposes for which livestock are kept, are vanishing and being replaced by an almost exclusive focus on generating food.

Animal source foods (ASF), mainly meat, milk and eggs, provide concentrated, high quality sources of essential nutrients for optimal protein, energy and micronutrient nutrition (esp. iron, zinc and vitamin B12). Access to ASF is believed to have contributed to the evolution of the human species' unusually large and complex brain and its social behaviour (Milton, 2003; Larsen, 2003). Today, ASF contribute a significant proportion to the food intake of Western

Figure 3.1 Fulani woman with traditional cheese in Northern Benin. By Frédéric Lhoste

societies (MacRae et al., 2005), but also play an increasingly role in developing countries.

Since the early 1960s, ASF consumption has increased in all regions except sub-Saharan Africa. The greatest increases occurred in East and Southeast Asia, and in Latin America and the Caribbean (FAO, 2010b). Structural changes in food consumption patterns occurred in South Asia, with consumer preference shifts towards milk and in East and Southeast Asia towards meat, while no significant changes could be detected in the other developing regions (Pica-Ciamarra and Otte, 2009). The growing demand for livestock products, a development termed the 'livestock revolution' (Delgado et al., 1999; Pica-Ciamarra and Otte, 2009), has been driven mostly by population growth in developing countries, while economic growth, rising per-capita incomes and urbanization were major determinants for increasing demand in a limited number of highly populated and rapidly growing economies. This has translated into considerable growth in global per capita kcal intake derived from livestock products, but with significant regional differences.

World population is projected to surpass 9 billion people by 2050. Most of the additional people will be based in developing countries while the population of developed regions is expected to remain stable (UNDP, 2009). About 3 billion new middle class consumers may emerge in the next 20 years (McKinsey, 2011). The concomitant 'nutrition transition' results in diet changes from staples to higher value foods such as fruit, vegetables and livestock products. Longer and more complex food chains have increased food diversity available for consumers, but also resulted in more common diets (Nugent, 2011).

FAO projects that by 2050, global average per-capita food consumption could rise to 3130 kcal per day. Agricultural production in the next 30 years will therefore present unprecedented challenges; it would need to increase by 60 per cent by 2050, with increases in crop and livestock production. Compared with 2005/07, this requires an additional production of 1 billion tonnes of cereals and 200 million tonnes of meat annually. Approximately half of the total increase in grain demand is predicted to be for animal feed. Globally, meat consumption per capita per year will increase from 41 kg in 2005 to 52 kg in 2050, reaching an average of 44 kg in developing countries and 95 kg in developed countries (OECD-FAO, 2009; Bruinsma, 2011; FAO, 2010b). Despite the absolute increase, growth rates in overall agricultural production are expected to decelerate as a consequence of the slowdown in population growth and because a growing share of population will reach medium to high levels of food consumption (Bruinsma, 2011).

Although global average production has increased, under- and malnutrition remains a large problem for those without access to animal source food and with food insecurity (Neumann et al., 2010), especially for poor children and their mothers. High rates of undernutrition and micronutrient deficiency among the rural poor suggest that, although often keeping livestock, they consume very little ASF. As iron, zinc and other important nutrients are more readily available in ASF than in plant-based foods, increased access to affordable ASF could significantly improve nutritional status, growth, cognitive development and physical activity and health for many poor people (Neumann et al., 2003). On the other hand, excessive consumption of livestock products is associated with increased risk of obesity, heart disease and other non-communicable diseases (WHO/FAO, 2003; Popkin and Du, 2003; Nugent, 2011). However, the nutritional aspects of animal products as part of human diets are not the main focus of this chapter.

Livestock production and the environment

The livestock sector has seen impressive production increases. Between 1980 and 2007, global beef output per animal grew at 0.4 per cent/year, milk at 0.3 per cent, pork at 0.8 per cent and poultry at 1.1 per cent (FAO Statistical Database [http://faostat.fao.org/default.aspx], accessed July 2012). These general trends mask high variation in productivity between species and livestock production systems, both within and between regions. The differences are larger in ruminants than in monogastrics for which industrial systems prevail in both developed and developing regions (FAO, 2010b). The most revolutionary change in the meat sector is in poultry; its share in world meat production increased from 13 per cent in the mid-1960s to 31 per cent in 2007 (FAO, 2010b).

The most important supply drivers over recent decades were cheap grain and cheap energy, technological change, especially in biotechnology, feeding and transport, together with a policy environment, including incentives, favourable to intensive production (FAO, 2010b). The growing demand for animal food products is being met increasingly through industrial systems, where meat production is no longer tied to a local land base for feed inputs or to supply animal power or manure for crop production (Naylor et al., 2005). There was a general shift from pasture-based ruminant species to feed-dependent monogastric species (Pingali and McCullough, 2010). In parallel, the non-food uses of livestock are in decline and are being replaced by modern substitutes (FAO, 2010b). Not only is animal draft power replaced by machinery and organic farm manure by synthetic fertilizers, but also insurance companies and banks replace more and more the risk management and asset functions of livestock.

The sector is also changing in regard to its contribution to poverty alleviation and income growth. While traditional livestock systems contribute to the livelihoods of 70 per cent of the world's rural poor, the dichotomy between large numbers of small-scale livestock keepers and pastoralists, and intensive large-scale commercial livestock production is growing. Generally, this goes hand-in-hand with shifts from multifunctional to commodity-specific production, local to globally integrated markets and from dispersed to clustered production. While livestock provide multiple roles and functions for the livelihoods of the poor, the same poor are especially vulnerable to environmental hazards and zoonotic diseases (FAO, 2010b).

Satisfying the growing demand for animal products while at the same time sustaining productive assets of natural resources is one of the major challenges for agriculture (Pingali and McCullough, 2010). Resource competition is likely to increase, for example through the decreasing availability of and competition for land and water (including from other land uses such as production of biofuels, urbanization and industrial development). Poor soil fertility and reduced access to fertilizer, overgrazing and deforestation, and loss of wild and agricultural biodiversity are further challenges. Thornton (2010) gives a comprehensive overview on possible modifiers of future livestock production and consumption trends, listing competition for resources, climate change, socio-cultural modifiers, ethical concerns and technological development. Many countries, especially in Africa, and small countries in Asia and Latin America are already struggling to adapt to current environmental degradation and climate variability. Climate change will exacerbate the existing challenges faced by the livestock sector. Hoffmann (2010a,b) gives a comprehensive overview on the consequences of climate change for animal genetic diversity, discussing the differences between developing and developed countries. Thornton (2010) and Hoffmann (2010b) illustrate the complex interaction of livestock and environment. At the same time as the livestock sector is a major contributor to greenhouse gas emissions, climate change itself may have substantial impact on livestock production systems.

The environmental footprint of agriculture, and particularly livestock production, has raised concerns in global assessments (e.g. MEA, 2005a,b; FAO, 2006a, 2010b; UNEP, 2007, 2010, 2011; Rockström et al., 2009; Foresight, 2011;

Grethe et al., 2011; McKinsey Global Institute, 2011; Westhoek et al., 2011) and in many studies (e.g. Gerbens-Leenes and Nonhebel, 2002; Pelletier and Tyedmers, 2010; Wirsenius et al., 2010). Livestock are the biggest land-user; they currently use about 30 per cent of the earth's entire land surface. This is mostly permanent pasture; but 33 per cent of global arable land is used to produce livestock feed. The sector also accounts for about 8 per cent of global water use, mainly for irrigation of feed crops. However, in arid areas, water consumed directly by animals or for product processing can represent a considerable share of total water use. Furthermore, the sector is a large producer of greenhouse gases (GHG), accounting for 18 per cent of GHG emissions, as measured in CO_2 equivalent – via enteric fermentation, land use and land-use change (directly for grazing or indirectly through production of feed crops) and manure management (FAO, 2010a).

The environmental impacts of livestock production occur at local, regional and global levels (FAO, 2006a). The rapid growth of the sector implies that much of the projected additional cereal and soybean production will be used for feeding enlarging livestock populations, resulting in increasing competition for land, water and other productive resources. This in turn puts upward pressure on prices for staple grains, potentially reducing food security (FAO, 2010b). A further concern in relation to products of animal origin is livestock's contribution to climate change and pollution. The projected need for additional cropland and grassland areas implies further risks of deforestation and other land-use changes, e.g. conversions of semi-natural grasslands. This will most likely not only lead to loss of biodiversity, but also to greenhouse gas and nitrogen emissions (FAO, 2010b; Westhoek et al., 2011). More research is needed related to livestock–water interactions. Such concerns are highly relevant when talking about sustainable diets.

Trends in breed diversity

The diversity of breeds is closely related to the diversity of production systems and cultures. Local breeds are usually based in grassland-based pastoral and small-scale mixed crop–livestock systems with low to medium use of external inputs. Over the past decades, agriculture has achieved substantial increases in food production, but accompanied by loss of biodiversity, including in animal genetic resources, and degradation of ecosystems, particularly with respect to their regulating and supporting services (MEA, 2005b). *The State of the World's Animal Genetic Resources for Food and Agriculture* (FAO, 2007) describes the link between livestock biodiversity and food security. Genetically diverse livestock populations provide society with a greater range of options to meet future challenges. Therefore animal genetic resources are the capital for future developments and for adaptation to changing environments. If they are lost, the options for future generations will be severely curtailed.

Diversity in livestock populations is measured in different forms: livestock breeds belong to different avian and mammalian species; thus species diversity can simply be measured as the number of species. Only about 40 of the about 50,000 known avian and mammalian species have been domesticated. On a global scale, just five species show a widespread distribution and particularly large numbers. Those species are cattle, sheep, chickens, goats and pigs, the 'big five' (FAO, 2007). Therefore, the majority of products of animal origin are based on quite narrow species variability.

The diversity presently observed within farm animal species is the result of a long history of human practice. At the sub-species level, diversity within and between breeds and the interrelationships between populations of a breed can be distinguished. Over millennia, a variety of breeds have been developed in a wide range of production environments. For livestock keepers, animal genetic diversity is a resource to be drawn upon to select stocks and develop (new) breeds. The term 'breed' does not have a universally accepted biological or legal definition. It originated in Europe and was linked to the existence of breeders' organizations. The term is now applied widely in developing countries, but it tends to refer to a socio-cultural concept rather than a distinct physical entity. FAO uses a broad definition of breeds which accounts for social, cultural and economic differences between animal populations and which can therefore be applied globally in the measurement of livestock diversity. According to FAO (2007) breeds can be categorized as local (reported by only one country) or transboundary (reported by several countries). The latest assessment identifies 7,001 local breeds and 1,051 transboundary breeds (FAO, 2010a).

Simply measuring breed diversity on the basis of number of breeds leads to biases due to the socio-cultural nature of the breed concept. However, between-breed diversity is classically considered as a major criterion to be taken into account when setting priorities for conservation. It has also been argued that additional criteria are needed for establishing those priorities, including within-breed variation (Barker, 2001; Caballero and Toro, 2002). The within-breed diversity may be lost due to random genetic drift and inbreeding in small populations, usually local breeds. However, within-breed diversity is also threatened within international transboundary breeds as a side effect of efficient breeding programmes, usually focusing on rather narrow breeding goals.

Various drivers influence the between- and within-breed diversity. Those drivers overlap with drivers of change in global agriculture and livestock systems including population and income growth, urbanization, rising female employment, technological change and the liberalization of trade for capital and goods. Those drivers had and have direct impact on human diets where a shift away from cereal-based diets is at the same time the cause and consequence of change in agriculture.

Together with increasing urbanization and globalization, market requirements are expected to change in the next decades. As many markets require standardized products and allow for little differentiation, some traditional and rare breeds might face increasing marketing difficulties. For example, the loss of small-scale abattoirs, often due to food safety regulation, can reduce the ability for breeds to enter niche markets or product differentiation. Developing countries' national strategies for livestock production aim at increasing food production rather than reflect the need for a genetic pool of breeding stock, although this is slowly changing due to the implementation of the Global Plan of Action for Animal Genetic Resources. Although breeding has to focus on what the market wants (mass or niche market), other factors also have to be taken into account. The choice of breeds/breeding used in the livestock sector needs to ensure the profitability of the farm, safeguard animal health and welfare, focus on conserving genetic diversity and promote human health.

Globally, about one-third of cattle, pig and chicken breeds are already extinct or currently at risk (FAO, 2010a). According to the last status and trends report on animal genetic resources (FAO, 2010a) a total of 1,710 (or 21 per cent) of all reported breeds are classified as being 'at risk'. Taking into account countries' different levels of breed population reporting, Woolliams et al. (2007) assume even higher shares of breeds at risk. Intensification of livestock production systems, coupled with specialization in breeding and the harmonizing effects of globalization and zoosanitary standards, has led to a substantial reduction in the genetic diversity within domesticated animal species (MEA, 2005b; FAO, 2007). Economic and market drivers were most frequently mentioned as threats for breed survival (FAO, 2009). The rate of breed extinction in the past was highest in regions that have the most highly-specialized livestock industries with fast structural change and in the species kept in such systems; however, several economically advanced countries have recently taken conservation action and broadened breeding goals (Hoffmann, 2011b).

Breeds adapted optimally to their habitat, in most cases not tailored to maximum meat or milk output, are increasingly being displaced by high-performance breeds – usually transboundary breeds for use in high external input, often large-scale, systems under more or less globally standardized conditions. In contrast to many local breeds, transboundary breeds provide single products for the market at high levels of output. Holstein-Friesian cattle – one of the most successful international dairy breeds – are reported to be present in at least 163 countries (http://dad.fao.org/, accessed July 2012). Large White pigs are present in 139 countries (http://dad.fao.org/, accessed July 2012); while in chicken commercial strains dominate the worldwide distribution. Extrapolating the figures of FAO (2006a) and assuming that the production increase between the early 2000s and 2009 is 100 per cent attributable to industrial systems, it can be estimated now that industrial systems provide 79 per cent of global poultry meat, 73 per cent of egg and 63 per cent of global pork production. This shows the increasing importance of transboundary breeds. Although the majority of milk is produced in small farms with an average herd size of three cows (IFCN, 2011), the share of transboundary dairy breeds or their crosses with local breeds is increasing. Unless selection within the local breed is incorporated in a structured crossbreeding programme, this may lead to the genetic 'dilution' of the local breed.

In parallel, consolidation in the breeding industry, especially in poultry and pigs, is ongoing (Gura, 2007). Breed utilization, genetic improvement and industry consolidation have major impacts on the genetic composition of transboundary breeds. A study in commercial chickens (Muir et al., 2008) indicated that more than 50 per cent of the original genetic diversity found in non-commercial breeds is absent in commercial pure lines. The genetic basis of a major commodity is reduced and may limit the capacity to respond to future needs. Due to global use of a few prominent bulls and a related fast increase in inbreeding, the effective population size of international dairy breeds, especially Holstein-Friesian, has declined (Fikse and Philipsson, 2007; Mrode et al., 2009; Philipsson et al., 2009).

In the case of crop diversity, FAO (2010d) noted that reliance on a smaller number of species and varieties not only results in erosion of genetic resources but can also lead to an increased risk of diseases when a variety is susceptible to new pests and diseases. This means increased food insecurity. The same arguments regarding increased risks hold for animal genetic resources. It should be considered that a rapid spread of pathogens, or even small spatial or seasonal changes in disease distribution, possibly driven by climate change, may expose livestock populations with a narrow genetic basis to new disease challenges.

A reduction of species and breed variety may also affect nutrition diversity. Meat quality is influenced by breed differences (e.g. Marshall, 1994; Suzuki et al., 2003; Bozzi et al., 2007; Lo Fiego et al., 2007; Sirtori et al., 2007), and species and breed differences are being exploited in many crossbreeding and selection schemes (e.g. Anderson, 1990; Beef CRC; Sheep CRC). For cattle milk, various interactions exist between breed, diet and location (including altitude) that contribute to the characteristic fatty acid profile of the milk (Bartl et al., 2008). Genetic differences also influence milk protein (e.g. casein) and processing quality. A review of milk composition for minor dairy species has shown large differences for macro- and micronutrients in different species and among breeds within the same species (Medhammar et al., 2011).

Meat quality is also heavily influenced by feeding and other environmental effects. Usually, grass-fed ruminants have higher levels of a-tocopherol, b-carotene, ascorbic acid, glutathione and nutritionally important long chain poly-unsaturated fatty-acids than feedlot-fed animals (Descalzo and Sancho, 2008; Wood et al., 2008). Meat from pasture feeding contains higher levels of antioxidants which in turn maintain the overall quality of meat and secondary products. Diet also affects meat flavour in both sheep and cattle but the components involved seem to be different. Meat from cattle raised on pasture is reported to be darker than meat from animals raised on concentrates (Priolo et al., 2001).

Reducing the environmental footprint – possible implications for breed diversity

Land and water availability are considered important future resource constraints for food security (FAO, 2011b). McKinsey (2011) estimated that more than 70 per cent of the opportunities to boost resource use efficiency lies in developing countries. Modelling results indicate that main points of intervention to reduce the environmental impacts of livestock production are: changes in nutrient management, crop yields and land management, grassland soil carbon restoration, husbandry systems and animal breeds, and feed conversion and feed composition on the supply side. On the demand side, shifts in consumption and reduction in food losses have been mentioned.

Due to the many synergies between enhancing production and reducing costs, it is already common practice to improve production efficiency. Comparisons for the USA indicate that improvements in genetics, feeding, health and management have reduced the carbon footprint for milk by 37 per cent if comparing a unit of milk produced in 2007 with that in 1944 (Capper et al., 2009) and for beef by 16.3 per cent if comparing a unit of beef produced in 2007 with that in 1977 (Capper, 2011). However, despite impressive relative efficiency improvements, life-cycle assessments show that the rebound effect of increased production and the absolute scale of the intensive landless livestock production still leads to considerable associated environmental impacts – beyond GHG emissions – and at different spatial and temporal scales (Pelletier, 2008; FAO, 2010b; Pelletier et al., 2010).

The future expected changes will most likely favour intensive livestock systems in which good feed conversion efficiency leads to reduced greenhouse gas emissions per unit of produce, which can be judged positively with regard to contributing products to sustainable diets. It is expected that breeding strategies using genomic information and transgenic approaches will in some sectors become more important to make farm animals more feed efficient and reduce the environmental footprint, thereby contributing to sustainability (Golovan et al., 2001; Niemann et al., 2011). However, the first 'beneficiaries' of such new technologies will most likely be the highly specialized transboundary breeds, such as the already dominating Holstein-Friesian cattle. Many recent scientific publications in the field of genomic selection focus on this breed (e.g. Hayes et al., 2009; Qanbari et al., 2010; Chen et al., 2011). Increasing concentrate feed efficiency will most likely lead not only to a shift towards highly productive and specialized breeds but also to a shift with regard to the species: away from ruminants towards monogastric species like poultry and pigs (FAO, 2010a,b). Except in marginal areas and extensive grazing systems, it can be expected that at the breed level, local breeds will more and more be replaced by transboundary breeds, leading to a further loss of local breeds and their manifold functions (Hoffmann, 2011b). Besides the loss of between-breed diversity an additional loss of within-breed diversity can be expected due to the further pressure on increasing yields of transboundary breeds by applying effective breeding programmes focusing on rather narrow breeding goals. Such losses due to effective breeding programmes might even be faster than in the past due to application of new biotechnologies.

From a biological conversion point of view, animal production systems consume more energy in feed than they generate in animal products. This is less of an issue in grazing systems where animals do not compete with humans over edible protein. Limited land availability for food production and the inefficiencies inherent in biological feed conversion have raised the importance of consumption and diets (Goodland, 1997; Gerbens-Leenes and Nonhebel, 2002). Studies following the recent attention to climate change propose to curtail the consumption of ASF in order to reduce anthropogenic greenhouse gas emissions (Stehfest et al., 2009; Wirsenius et al., 2010; Garnett, 2011; Grethe et al., 2011; Westhoek et al., 2011). Most studies propose to lower meat demand in industrialized countries only. Although such reductions would have only a small positive effect on food security in developing countries, they would have positive effects for human health, result in a less unequal per capita use of global resources, lower greenhouse gas emissions and could ease the introduction of higher animal welfare standards. The need for a broader view on sustainability, beyond a single focus on reducing GHG emissions, has been stressed by several authors (e.g. MacMillan and Durrant, 2009; Deckers, 2010).

A further option to fulfil the globally growing demand for animal source products could be the use of 'artificial' meat or *in-vitro* produced meat. In this trajectory, changes in food composition could improve health characteristics, and closed industrial production technology may result in more hygienic and environmentally friendly characteristics than 'traditional' meat (Thornton, 2010). While this may contribute for example to the health aspect of a sustainable diet, it may possibly not fulfil the criterion of 'cultural acceptance' across all societies. Also, a large-scale development and uptake of *in-vitro* meat might have severe effects on the livestock sector including employment and most likely a negative effect on the diversity of animal genetic resources. *In-vitro* meat and food fortification also contradict the concept of sustainable diet which stresses the importance of food-based approaches (Allen, 2008).

Finally, the reduction of food losses and wastes will be critical, as they imply that large amounts of the resources used in, and emissions and pollution caused by food production are used in vain. ASF, being highly perishable and connected to food safety risks, incur high losses along the chain. Losses of meat and meat products in all developing regions are distributed quite equally throughout the chain, while in industrialized regions, about 50 per cent of losses occur at the end of the chain. Approximately 40–65 per cent of total milk food losses in industrialized regions occur at the consumption level, while in developing regions, milk losses during post-harvest handling and storage, as well as at the distribution level, is relatively high (FAO, 2011c). Food waste disposal finally releases more GHG and water pollution.

In summary, past efforts to increase intensive production system yields and productivity have been undertaken mainly within a framework that has aimed to control conditions and make production systems uniform (FAO and PAR, 2011), which tends to favour the use of uniform breeds and therefore tends to undermine animal genetic diversity. This has led to a narrow set of breeds and management practices. The actual trends in combination with the growing demand for products of animal origin for human diets continue to drive a further shift in agricultural systems towards more intensive systems. This will most likely favour international transboundary breeds instead of local breeds. At species level, the shift towards poultry and pigs will continue.

Whether products especially from intensive systems can contribute to a sustainable diet depends on the systems' compatibility with regard to the rather complex requirements of the sustainable diets concept, namely being protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources. However, even if many aspects do contribute to a sustainable diet, a loss of animal genetic diversity appears to be quite likely at a global level. Given the important role of biodiversity in the sustainable diet definition, breed loss constitutes a negative impact on sustainable diets.

Solutions with focus on sustainable diets favouring animal genetic diversity

Inevitably, cultural and social roles of livestock will continue to change, and the nutrition transition will continue, including its undesirable health effects (Thornton, 2010; Nugent, 2011). The scenarios described above do not give rise to a bright future for animal genetic diversity even if sustainable diets are propagated. However, there is hope because a wide range of agricultural practices are already available to improve production in sustainable ways (e.g. FAO and IAEA, 2010).

Arguments in favour of local, mostly low-input breeds are based on the multiple products and services they provide, mostly at regional and local level. Firstly, their ability to make use of low-quality forage results in a net positive human edible protein ratio (FAO, 2011d). Secondly, under appropriate management, livestock kept in low external input mixed and grazing systems provide several ecosystem services. Thirdly, as a result, and linked to local breeds' recognition as cultural heritage, linkages to nature conservation need to be further explored and strengthened (Hoffmann, 2011a). All this is in harmony with the qualities of a sustainable diet.

Aiming for the improvement of the livestock sector's environmental performance will lead to different, locally tailored solutions, favouring certain environmental goods over others. Such systems are a prerequisite for production of food for sustainable diets and may add value to breed diversity. Besides traditional systems, a range of different innovative approaches to agricultural production exist, seeking to combine productivity and increased farmer incomes with long-term sustainability (FAO and PAR, 2011). In European countries, there is an increased emphasis on, and economic support for, the production of ecosystems goods and services, with a possibly positive effect on the role of local breeds, rural employment and survival chances for small-scale abattoirs. However, the efficiency of the EU agri-environmental programmes to breed conservation has been questioned (Signorello and Pappalardo, 2003) as payments are often below opportunity costs and little prioritization is undertaken.

Figure 3.2 Cheese tasting in Mostar, Bosnia-Herzegovina. By Irene Hoffmann

In this context the ability of livestock, especially ruminants, to transform products not suitable for human consumption such as grass and by-products, into high-value products such as dairy and meat, plays a role. Grasslands have been identified as critical for C-sequestration, soil and vegetation restoration, and livelihoods for poor people, mostly pastoralists. Grasslands occupy about 25 per cent of the terrestrial ice-free land surface. In the early 2000s they harboured between 27 and 33 per cent of cattle and small ruminant stocks, respectively, and produced 23 per cent of global beef, 32 per cent of global mutton and 12 per cent of milk (FAO, 2006a). In Europe, so-called high nature value farmlands make up approximately 30 per cent of grasslands (EU-15 countries); they are considered to be part of Europe's cultural heritage and are mostly Natura 2000 sites. However, only an estimated 2–4 per cent of dairy production and around 20 per cent of beef production comes from high nature value grasslands (Westhoek et al., 2011).

One of the six priority targets of the 2011 EU Biodiversity Strategy is 'To increase EU contribution to global efforts to avoid biodiversity loss'. The accompanying impact assessment suggests that approximately 60 per cent of agricultural land would need to be managed in a way that supports biodiversity to meet this target, including both extensively and intensively managed areas under grass, arable and permanent crops. A mosaic of habitats with generation of positive co-benefits for production, biodiversity and local people would lead to what Scherr and McNeely (2008) called diverse types of 'eco-agriculture' landscapes. Also Benton et al. (2003) conclude that the re-creation of ecological heterogeneity at multiple spatial and temporal scales is key to restoring and sustaining biodiversity.

There is sufficient intensification potential in extensive systems without having to change the breed base. A recent life-cycle analysis for the dairy sector also showed a huge potential for moderate efficiency gains in developing countries (FAO, 2010c). On the contrary, well-adapted, hardy breeds are advantageous in utilizing the vast areas under rangelands (FAO, 2006b).

However, focusing on local and regional rather than global (i.e. GHG) aspects of sustainability also has its drawbacks. Measures such as improved animal welfare may lead to less efficient production, and thereby may just shift the negative environmental impact elsewhere; other measures may lead to higher costs for farmers. However, if done properly, measures taken locally at the supply and demand side would lead to lower societal costs by reducing local environmental impacts, animal welfare problems and public health risks (Grethe et al., 2011; Westhoek et al., 2011).

The main criticisms of ecological approaches were summarized during an expert workshop on biodiversity for food and agriculture as follows: (i) adoption of ecological approaches to farming reflects a romantic and backward-looking perspective, (ii) they will require even larger subsidies, and (iii) they are labour and knowledge intensive. To overcome this scepticism, innovation and development for new approaches will be essential, while a critical assessment of existing research results might be advisable, because most cost-benefit analyses comparing high-input systems with sustainable agricultural systems tend not to account for the manifold benefits agricultural systems can provide (FAO and PAR, 2011). In view of the existing agricultural subsidies in many countries it cannot be argued that commercial breeds are associated with some ideal free market equilibrium price. On the other hand, society cannot expect farmers to maintain breed diversity for the public good (ecosystem services or future option values) unless society is willing to compensate them up to the opportunity costs they incur for not using a more commercial breed (Drucker et al., 2005; Hoffmann, 2011b).

The recognition of the value of nutritional and dietary diversity is becoming an important entry point for exploring more ecologically sustainable food systems. Consumers may play a key role by improving their access to information and their control over what they choose to consume. Undoubtedly, use of diversity requires significant knowledge and skills. There are questions about the robustness of consumers' preferences regarding organic and local food, particularly in times of considerable economic uncertainty (Thornton, 2010). Limited economic resources may shift dietary choices towards cheap, energy-dense, convenient and highly palatable diets providing maximum energy (Drewnowski and Spencer, 2004). Consumption shifts, particularly a reduction in the consumption of livestock products, will not only have environmental benefits (Stehfest et al., 2009), but may also reduce the cardiovascular disease burden (Popkin and Du, 2003). However, changing consumption patterns is considered a longer-term process involving societal and cultural shifts.

Conclusions

In view of the uncertainty for future developments, a wide diversity of genetic resources is the best insurance to cope with unpredictable effects. There is no question that demands for animal products will continue to increase in the next decades and a further push to enhance livestock productivity across all production systems is needed to lower the environmental footprint of livestock production. At local level, there are many overlaps between environmental sustainability goals, sustainable production and providing sustainable diets. However, many of the required new technologies to increase resource efficiencies at global level will accelerate the structural change of the sector towards more intensive systems and thereby the losses of animal genetic diversity even if sustainable diets are aimed at. Taking into account the complexity of issues associated with the elements of a sustainable diet, more emphasis will need to be placed on avoiding the erosion of genetic diversity.

Providing sustainable diets can only be achieved with a combination of sustainable improvement of livestock production and a combination of policy approaches integrating the full concept of sustainable diets, accompanied by awareness raising for the value of biodiversity and investing in research as basis for sound decisions. Numerous research questions still require investigation, spanning different fields of science. With regard to livestock diversity and in view of uncertainty of future developments and climate change this implies the need to develop simple methods to characterize, evaluate and document adaptive and production traits in specific production environments. It also requires better identification of nutritional differences between ASF from different breeds and productions systems. The lack of such data is currently one of the constraints to effective prioritizing and planning for the best use of animal genetic resources measures in a sustainable development of the livestock sector and food systems. Intensifying research to develop life-cycle assessments and to include delivery of ecosystem services in the analysis recognizing and rewarding the sustainable use of biodiversity in well-managed rangelands with local breeds will also be one major task. Addressing the various spatial and temporal connections and trade-offs, and reaching out to different stakeholders in the value chain are considerable challenges. The concept of sustainable diet and the essential role of animal genetic diversity need to be addressed through awareness and educational programmes. Eating means not just ingesting food, but it is also a form of enjoyment and cultural expression.

Note

The views expressed in this publication are those of the author(s) and do not necessarily reflect the views of the Food and Agriculture Organization of the United Nations

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