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► **To cite this version:**

Jean-François J.-F. Hocquette, Vincent Chatellier. Prospects for the European beef sector over the next 30 years. *Animal Frontiers*, 2011, 1 (2), pp.20-28. 10.2527/af.2011-0014 . hal-02645905

**HAL Id: hal-02645905**

**<https://hal.inrae.fr/hal-02645905v1>**

Submitted on 29 May 2020

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# Prospects for the European beef sector over the next 30 years



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## Implications

The economy and the roles of livestock production within society have changed much in recent years, and this change is set to continue and intensify. Not only beef supply chains, but also animal research and development on the competitiveness of these chains, must have new strategies and revised objectives to meet the challenges.

- Globally, livestock production (and specifically beef production) plays an important role in maintaining food supplies, especially supply of good-quality protein. In addition, the demand for animal products including meat is increasing, notably in developing countries.
- In the 27 member states of the European Union, beef production is slowly declining and the trade balance has been negative since 2003. In the future, the level of beef production will be closely linked to dairy sector dynamics, public policies (World Trade Organization and Common Agriculture Policy), and price balance between crops and animal production. The context in which beef is produced has changed considerably. Some issues (e.g., animal welfare, protection of the environment, pasture-based systems) concern not only cattle but also all types of ruminants.
- Recent developments in animal genetics and genomics up to metabolomics will help to investigate the regulation of phenotypic variation in livestock, including the variation in sustainability traits such as efficiency of nutrient use, emissions (nitrogen, phosphorus, and greenhouse gas), health, product quality, and most important, robustness.
- Research should be targeted at practical issues, for instance the development of predictive approaches for the development of precision livestock farming, which has proven to be efficient at increasing, step by step, the efficiency of production and consequently competitiveness of the beef supply chain.
- Focusing on efficiency of nutrition is also an important challenge to limit the use and reduce the cost of using high-quality nutrient resources as animal feed that can also be used for human food, and to reduce potentially harmful emissions such as carbon, methane, or nitrogen. The potential to maximize forage utilization by ruminants requires improving our knowledge of forage intake and digestion. However, there is also an increasing demand to evaluate feeds based on multiple criteria including nutrition, product quality, animal health and welfare, traceability, and sustainability.

- Because we are using more and more limited natural systems, we should move toward pasture systems and ecologically intensive systems, forcing us to work on the ecological footprint of animals. At the same time, the consequences of global change on livestock systems should be taken into account within our research.
- Better animals, better feed, and better nutrient utilization with more autonomous farming systems would ensure better incomes for farmers while protecting the environment and producing typical products of specific and high quality.

**Key words:** beef production, bovine sector, Common Agriculture Policy, European Union, genetics, quality, World Trade Organization

## Consumption, Production, and Exchange

In the 27 member states of the European Union (EU-27), meat consumption was, on average, 77 kg per capita for the year 2010. Beef represented 21% of the total meat consumed or 16 kg per capita (against 41 kg for pork meat, 17 kg for poultry meat, and 3 kg for sheep and goat meat). This level of meat consumption is less than that observed in Argentina, Brazil, the United States, and Australia (Table 1), where beef represents a greater share of the total meat consumption (with a peak of 58% in Argentina). European consumption of meat is, however, significantly greater than in other countries such as Russia, China, and Japan and much greater than in India, where a vegetarian diet is predominant.

The purchasing power of consumers is a key determinant of the level of meat consumption per capita. This is particularly true in the beef sector where prices are generally greater than those for other forms of animal protein. Low competitiveness of beef is mainly due to the long duration of the production cycle of bovine cattle and to a decreased feed efficiency compared with poultry or pigs. The recent development of beef consumption in Asian countries such as Japan or South Korea, which have benefited from a favorable economic situation, confirms the importance of this criterion. China's beef consumption has grown slowly but steadily, mainly in urban areas where economic growth is strong. This increase is likely to continue in the near future as in Brazil (Table 2). In the 12 new European Union (EU) member states (Table 3), where the purchasing power of consumers is less than in the EU-15, pork is much preferred (only 4 kg of beef per capita compared with 12 kg in Germany, 19 kg in the United Kingdom, and 25 kg in France, Table 3). However, beef consumption does not only depend on economic considerations:

- In some countries, religions and beliefs have a significant impact on food choices of inhabitants: consumption of pork is pro-

**Table 1. Consumption of beef meat and total meat per capita (kg): 2010 and 2025 perspectives<sup>1</sup>**

Country	Beef			Total meat			Beef/total meat (%)	
	2010	2025	2025/2010	2010	2025	2025/2010	2010	2025
Argentina	55.7	55.2	-0.5	96.2	106.4	+10.2	58	52
Brazil	39.8	49.1	+9.3	94.0	106.9	+12.8	42	46
United States	38.2	38.0	-0.1	109.2	109.0	-0.1	35	35
Australia	35.3	34.7	-0.7	92.7	96.7	+4.0	38	36
EU-27	16.4	16.0	-0.4	77.7	80.1	+2.4	21	20
Russia	16.0	16.5	+0.4	56.1	67.3	+11.2	29	25
Japan	9.5	11.6	+2.1	44.7	50.6	+5.9	21	23
China	4.2	6.1	+1.9	53.0	72.9	+19.9	8	8
India	1.8	2.0	+0.2	4.1	4.4	+0.3	44	45

<sup>1</sup>FAPRI, 2011.**Table 2. Beef sector in European Union (EU)-27 and some other countries: 2010 and 2025 perspectives<sup>1</sup>**

Country	Production (1,000 tonnes)			Consumption (1,000 tonnes)			Net trade (1,000 tonnes)		
	2010	2025	2025/2010	2010	2025	2025/2010	2010	2025	2025/2010
United States	11,781	12,982	1,201	11,865	13,631	1,766	-70	-654	-583
Brazil	9,789	14,955	5,166	8,008	11,395	3,387	1,781	3,560	1,779
EU-27	7,870	7,689	-181	8,200	8,102	-98	-330	-413	-83
China	5,550	7,957	2,407	5,528	8,464	2,936	22	-507	-529
India	2,850	3,555	705	2,150	2,848	698	700	707	7
Argentina	2,600	3,119	519	2,303	2,602	299	297	517	220
Australia	2,080	2,579	499	760	868	108	1,317	1,710	393
Russia	1,300	946	-354	2,235	2,110	-125	-935	-1,163	-228
Japan	510	431	-79	1,207	1,364	157	-694	-934	-240

<sup>1</sup>FAPRI, 2011.**Table 3. Beef sector in some member states of European Union (EU)-27 (2010) including some new member states (NMS)<sup>1</sup>**

Country	Bovine cattle (1,000 animals)	Dairy cows (1,000 animals)	Suckler cows (1,000 animals)	Slaughter of bovine cattle (1,000 animals)	Consumption of beef (1,000 animals)	Consumption per capita (kg/year)
France	19,307	3,513	4,189	1,297	1,619	25.0
Germany	12,810	4,183	717	1,152	1,057	12.9
United Kingdom	10,115	1,847	1,658	922	1,221	19.7
Ireland	6,617	1,131	1,107	550	87	19.5
Spain	6,277	837	1,992	448	493	10.7
Italy	6,056	1,851	424	914	1,396	23.1
Netherlands	3,970	1,510	80	168	248	15.0
Belgium	2,601	521	529	207	158	14.6
Austria	2,019	535	264	215	148	17.6
Denmark	1,642	574	112	99	111	20.0
EU-15	76,019	17,599	11,886	6,282	7,217	18.1
Poland	5,724	2,538	118	365	132	3.5
Romania	2,501	1,431	16	22	41	1.9
Czech Republic	1,403	381	182	75	95	9.1
NMS-12	13,322	5,834	543	612	419	4.1
EU-27	89,341	23,433	12,429	6,895	7,636	15.2

<sup>1</sup>European Commission, 2011.

hibited in Islam, and animals are sacred in Hinduism. In the EU, these considerations are not as important as in other countries such as India, Indonesia, or Saudi Arabia.

- For cultural and educative reasons, national dietary patterns are more or less resistant to the increasing internationalization of lifestyles and to lifestyle changes in favor of ready-to-use products. Consumers are influenced by technological innovations that make meat more or less well adapted to their expectations (practical use of the product, flavor, tenderness, or human health). Compared with other meat types, one challenge for the beef industry would be to propose more convenient or ready-to-use products.
- Consumers are also more or less sensitive to health crises. In Germany, for example, the bovine spongiform encephalopathy crises in 1996 and 2001 resulted in a significant decline in beef consumption.
- Moreover, some ethical (e.g., animal welfare, slaughter of animals) and environmental (e.g., water quality and biodiversity) considerations are taken into account more and more by European consumers.
- Beef and veal are not always available, especially in countries where production is naturally limited by the presence of low-forage areas. In the EU, beef production is, for example, more developed in northern countries (France, Germany, and Ireland) than in southern countries (Greece and Italy) where the climate is clearly a disadvantage for this type of production.

Based on the estimations of the Food and Agriculture Organization of the United Nations (**FAO**) and the Organization for Economic Cooperation and Development (**OECD**), the total world consumption of beef is expected to grow at a rate of 1.5% per year between 2010 and 2020 (FAO-OECD, 2011). Because this increase is slower than that expected for poultry (+2.4% per year) and pork (+1.8% per year), the weight of beef in total meat consumption will decrease slightly (with the exception of a few countries, including Brazil). The increase in beef consumption is primarily due to the growth of world population (+1.1% per year, about 200,000 people per day) and a transformation of diets in developing countries (FAO, 2010). Indeed, the annual growth rate of beef consumption is estimated to be +0.6% for OECD member countries (mainly developed countries) and +2.1% for nonmembers.

According to the Food and Agricultural Policy Research Institute (**FAPRI**), European consumption of beef per capita and per year is expected to decline slightly in the coming decades from 16.4 kg in 2010 to 16 kg in 2025 (FAPRI, 2011). These forecasts go in the same direction as those of the European Commission, which predict a greater difference: -1.1 kg between 2010 and 2020 (European Commission, 2010a). Stability in the individual consumption of beef is also foreseen in the United States, Australia, Argentina, and Russia and in most developed countries where meat consumption seems to have peaked. It should, however, continue its upward trend in China, Japan, Mexico, Brazil, and more generally, in many developing countries (except India) where economic growth contributes to an improvement in the purchasing power of consumers.

According to FAPRI estimates, the EU will rank fourth worldwide in terms of beef consumption (after the United States, Brazil, and China) and fourth largest in terms of production (after Brazil, the United States, and China) in 2025. The EU went into deficit in beef in 2003 and should remain in this situation in the coming decades (Table 2). In 2025, EU

beef production (7.68 million tonnes) should be less than domestic consumption (8.10 million tonnes, about 13% of world consumption), so the trade balance is estimated at -0.41 million tonnes in 2025. The predictions made by the European Commission confirm this trend: -0.54 million tonnes in 2020.

European beef is produced in two categories of farms: i) specialized beef farms with suckler cows or young bovine cattle; and ii) dairy farms for which beef production is a by-product of milk production. In the EU-27, dairy farms make up two-thirds of the bovine cattle herd (it is sometimes more than 80% in northern countries or in some new member states). The heterogeneity of the European beef sector is reflected in terms of specialization, intensification, types of animals (suckler cows, calves, heifers, young cattle, bulls, and steers), and production systems (breeds of animals or feed systems). This heterogeneity depends on natural environment (agricultural potential of soils, climate, altitude, and topology), agricultural traditions, and also public policies. Farm restructuring (including that resulting from increased labor productivity), modernization of production facilities (buildings and equipment), and new technologies (genetic selection and feed) have played a significant role in reducing the diversity of European farms.

The expected decline in EU beef production will be mainly due to a decrease in the total number of cows (Buczinski, 2010). The EU dairy herd has been steadily declining (23.4 million of dairy cows in the EU-27 in 2010). The increase in milk yield per cow, which is closely linked to genetic progress, has led to a decline in the number of dairy cows in all EU member states (with an unchanged volume of milk production). The number of dairy cows fell, for example, by 40% in France between 1980 (7.1 million animals) and 2010 (4.1 million animals), whereas the total production of milk is quite comparable. The reduction in the dairy herd inexorably leads to a reduced supply of beef. This phenomenon is even more prevalent in northern countries of the EU (Denmark, the Netherlands), where intensification is high because of a lack of agricultural land. Only a significant increase in EU exports of dairy products would be likely to counterbalance this change in the coming years (by encouraging the development of the dairy herd). The European herd of suckler cows has been stable for many years (12.4 million animals in 2010) and depends on the profitability of this sector (not very good at the moment) and on direct subsidies granted to producers by public policies. This herd is highly concentrated in four member states (Table 3), namely France (34% of European livestock), Spain (16%), the United Kingdom (13%), and Ireland (9%). A long-term development of the European herd of suckler cows is still possible, at least in some countries (including France) with substantial fodder surfaces; this development involves giving better prices to beef producers and maintaining an effective tariff protection, in particular with South America.

In the beef sector, international trade represents 10% of world production. In the coming years, trade flows are expected to increase and to be influenced by production costs, trade policies (tariffs), and sanitary measures. The European exports of beef, which were equivalent to 15% of the beef production in 1990, have become marginal over time. Not only is EU beef production uncompetitive compared with that of other countries, but European production is declining faster than consumption. The 12 new EU member states have exacerbated this phenomenon: beef production is low in these countries (Table 3) and demand is increasing. According to the European Commission, EU exports of beef should represent only 1% of the domestic production in 2020. European imports of beef, mainly

from the Mercosur countries, have remained relatively stable since 2000. The imports are expected to reach 0.6 million tonnes in 2020 (8% of domestic consumption).

## World Trade Organization and Common Agricultural Policy

In the long run, the European beef sector is potentially sensitive to the decisions that will be taken in the next agreement of the World Trade Organization (WTO) and in the Common Agricultural Policy (CAP). The Doha Round, which started in 2001, has not been finalized yet due to disagreements among countries concerning European agriculture including the beef sector through three topics:

- How direct payments are granted to beef producers. To be considered compatible with the criteria defined in the WTO (Article 6 of Annex 2 of the Uruguay Round Agreement on Agriculture), subsidies paid to farmers should be decoupled (Swinbank, 2008), meaning that they should not be awarded on the basis of agricultural production from farms or on the basis of evolution of prices (domestic or international). To accommodate this requirement, the EU authorities decided to reform the CAP in 2003 and 2008. They made mandatory the application in all member states of a decoupling of direct payments to avoid the risk that a future WTO agreement would require a reduction of the EU agricultural funds (including funds for the beef sector for which the average amount of direct aid is often greater than incomes). In the European Commission proposals for the post-2013 CAP, an exemption to this general rule was allowed for the specific case of suckler cows. Thus, for member states who express a desire, coupled support may be maintained. Considered unnecessary by some member states (such as Ireland and Germany), this option was judged to be necessary by the French authorities. In France, the government feared that the decoupling of aid would lead to a drastic decline in the herd of suckler cows and thus in the production of beef, especially in mountain areas where alternatives are often scarce. With decoupling, some farmers could adopt a strategy not to produce beef while continuing to receive direct payments historically allocated to this production. The European offer of beef (and its territorial distribution) could be sensitive to changing rules for awarding direct aids to farmers in the future.
- Aid granted by public authorities to promote exports of agricultural products on international markets. The level of export refunds has decreased substantially in the EU over time: from 10 billion euros in 1990 to less than 1 billion in 2010. In the next World Trade Organization (WTO) agreement, these aids will probably be prohibited. The European beef sector need not fear a prohibition because exports of beef have become marginal (primarily with the bordering countries) and should remain so in the coming decades. Export of beef will mainly concern some special beef (in terms of quality) and some live animals (export of know-how in genetics).
- Border protection through tariffs (which is different than border protection through EU bans on growth promotants or on other types of products for safety reasons). At this stage of the

multilateral negotiations in the (delayed) Doha Round, it has been agreed that the future reduction in customs duties on agricultural and food products will be applied according to what is called a tiered formula. This means that a 50% reduction in customs duties is foreseen (compared with a past reference period) for products whose final consolidated tariff (or the *ad valorem* equivalent, AVE) is less than 20%; a 57% reduction for the 20 to 50% AVE bracket 64% for the 50 to 75% bracket and 70% for the AVE bracket exceeding 70% (as the beef sector). The sensitivity of different European agricultural products to this possible future reduction in customs duties is not standard because the difference between the EU price and the international price varies from one product to another. In the beef sector, the EU price is generally significantly greater than that of the large exporting countries (Institut de l'Élevage, 2011). Customs duties applied at the EU borders are still substantial: 12.8% of the value and 3 euros per kilogram for boned, chilled, and frozen meat. With the exception of the possible (justified) classification of the beef tariff headings as sensitive products (products benefiting, by way of exception, from a lower reduction in customs duties), a large reduction in tariff protection prompts the fear of downward pressure on the price of EU beef. As discussed below, a low price of beef and consequently a low income for beef producers will not help to sustain rural communities in some specific parts of Europe.

In addition to multilateral trade agreements, the future dynamics of the European beef sector will also depend on internal choices concerning the next CAP reforms (European Commission, 2010b). European production of beef in the coming decades will be particularly sensitive to changes in the dairy sector (i.e., the pace of development of milk production to meet growing international demand for dairy products). The abolition of milk quotas in 2015 and the introduction of decoupling of direct payments could encourage the development of milk production in the most competitive geographical areas at the expense of other less profitable agricultural production. For example, in a country like Ireland, milk production is likely to grow at the expense of suckler cows. In France, an increased concentration of the herd of suckler cows in disadvantaged areas is possible. In geographical areas where cereal production is possible, the risk of abandoning beef production for the benefit of cereal crops is a serious threat, especially if cereal prices remain durably high (Chatellier, 2011). Should it become necessary to increase the herd of suckler cows to maintain a certain level of beef production in the EU, France is surely the country with the greatest potential for doing so (due to a low population density in rural areas and to its large fodder areas).

The specialized beef farms will also be very sensitive to changes in the amount of direct aid. Given the level of production costs and the selling prices of animals, the income of these farms is, on European average, well below the amount of direct aid. In the context of the future CAP reform and EU financial perspectives for the 2014-2020 period, the issue of targeting direct aid will be crucial for the beef sector. To support this sector in the long term, direct aid should be better allocated, in the sense of payment for environmental and territorial services to preserve rural employment.

The level of beef production will also depend heavily on price relationships between crop and animal production. The beef sector needs more

stable prices, given the length of the beef production cycle (long) and the low return on capital. In this sense, it seems important that the future CAP maintains some instruments to regulate the market (public intervention when the price drops to a low level) and encourages young farmers to start up. It also seems necessary to build some new tools to help European producers to deal with price volatility. The fight against price volatility requires modifying tax policies, adopting new risk management instruments and implementing a better coordination of agricultural policies at the international level (Pisani and Chatellier, 2011).

## Social Considerations

One major social consideration is strongly associated with competitiveness of the beef supply chain. Ensuring a minimum income for beef producers is vital to sustaining vibrant rural communities, which is important for local governments. Indeed, the more producers in rural areas, the more other activities will be developed, and this is highly important for the economic development of mountain grassland areas in which no other agricultural activity is possible except ruminant breeding for the production of typical meat and dairy products. This concerns not only bovine but also ovine breeding. We can observe here a convergence of objectives between social expectations, competitiveness of the beef supply chain, and the assurance of beef quality linked to geographical origin.

Many other social considerations have to be taken into account mainly in developed countries because consumers of beef are citizens who are expressing their thoughts and emotions in the modern media. The industrialization of animal production systems during the last 50 years and the progressive distance of cities from farms have raised questions concerning livestock production systems, including animal welfare. In the context of safety crises and media events (boycotts of veal meat, illicit trading, use of hormones, and the “mad cow” crisis), citizens believe that herbivores should eat grass, which is a natural and cheap product available in pastures. This natural way of production is supposed to preserve animal welfare as well as to protect the environment, two points expected by citizens at least in France (Tavoularis, 2008) and which we will discuss in more detail.

In the Amsterdam treaty (1997), the European Union acknowledges that animals are sentient beings and stipulates that animal welfare shall be taken into account in farming. Consumers in the EU support the improvement of animal welfare in Europe and are prepared to pay more for animal welfare-friendly products. The objective of research and development activity is thus to improve the general level of animal welfare by introducing standard welfare indicators (Botreau et al., 2009). Some basic studies are still needed to better characterize the welfare state of an animal and to better understand the mechanisms of plasticity allowing animals to adapt, in a suitable and timely manner, to a variety of farming conditions. Novel and cheap biosensors or other technological innovations are new tools for online monitoring of animal health or reproductive status to better assess overall animal welfare. Noninvasive practices such as simple manipulation of farming environmental parameters (light, odor, temperature, noise, food delivery, and social partner effects) also have to be taken into account to improve animal welfare. Research should take advantage of modern techniques such as imaging, “omics,” and modeling. Because animal welfare is multifactorial, quantitative modeling is a key tool to be developed to better assess animal welfare, taking into account all the factors that

influence animal welfare. Putting animal welfare assessment into practice will be the last, but not the least, challenge in this area.

## Environmental Considerations

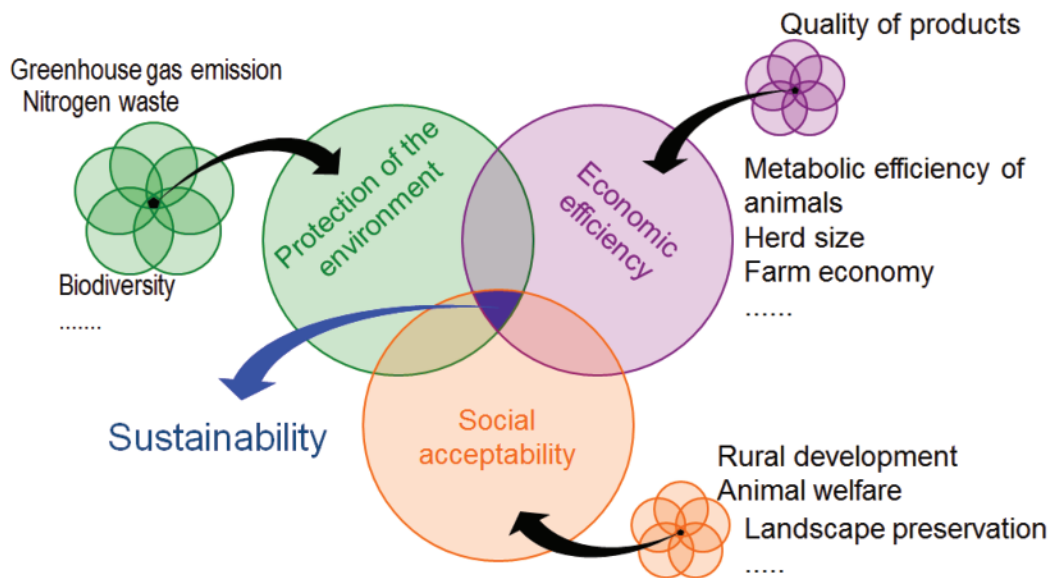
For millennia, human beings have lived in harmony with animals, but this is less the case because of an increased distance between the majority of the population living in cities and those living on farms in rural areas, with fewer connections between them. In addition, our natural resources are being exploited in an unsustainable manner to maintain growth of livestock production systems to satisfy the increasing demand for animal products including beef. Furthermore, the emergence of new challenges concerning global climate change is a further major problem for agriculture, especially for beef production, which has been calculated to be among the worst in terms of carbon footprint. Therefore, the consequences of global change on livestock systems should be taken into account in agricultural research and practices. More precisely, livestock sector governance should be strengthened to ensure that its development is environmentally sustainable (Figure 1; FAO, 2009). In addition, farmers are now looking for robust animals; that is, animals that can adapt more easily to environmental challenges (Friggens et al., 2010).

Livestock have been implicated in many negative processes: land use change especially in developing countries, nutrient excretion, fossil energy use (e.g., feed production and transportation across oceans), competition for food, and emission of greenhouse gases. Only a few examples of these injurious situations and the potential ways to reduce them will be detailed here; these topics were detailed and discussed in the first issue of *Animal Frontiers*.

First, the increasing general awareness of the environmental problems tied to cattle farming should prompt a series of research and practical initiatives designed to assess the environmental impacts of farming systems parallel to their economic performance (Veysset et al., 2010). Better and harmonized methods with increased precision to assess the ecological footprint of animal products should be developed and applied to all production types (Hermansen and Kristensen, 2011).

Second, research is still needed to reduce greenhouse gas emissions, especially methane, from livestock production, and especially from beef. This can be achieved by different means, for instance, by the improvement of existing farming systems and the development of innovative new systems that minimize waste and also by basic research on ruminant microbiota to reduce methane production during the digestion process (Martin et al., 2010), although it is difficult to see how to convert scientific results in this area into practice (Hermansen and Kristensen, 2011). It is noteworthy to indicate here that methane emissions from cattle are correlated with the quantity and quality of ingested cell walls.

Third, intensification of animal farming systems induced an increase in nitrogen spillage in the soil-crop-animal interaction. In the next future, the strategy should be closure of the nutrient cycle at the farm level, which can only be obtained when an integrated whole system approach is used. This implies a greater feed autonomy, and especially (closely linked) forage autonomy of farms. In addition, more basic research and modeling approaches (Martineau et al., 2011) are needed to reduce nitrogen excretion into the environment through the optimization of digestive and metabolic functions, an improved understanding and prediction of dietary nitrogen utilization for production, and a reduced excretion in urine and feces.



**Figure 1.** Sustainability of livestock farming is a multidimensional approach with 3 major dimensions, which result in turn from the aggregation of different criteria.

At the same time, livestock farming systems offer numerous benefits: producing food from human-inedible sources, preserving ecosystem services, recycling plant nutrients, and providing social benefits that have been previously discussed. But livestock farming systems can offer even more such as helping with the sequestration of carbon in the soil, preserving plant and insect biodiversity, and conserving landscape for tourism purposes, depending on the farming practices. Sequestration of carbon in the soil can reach 50% of the emissions and is greater when the stocking rate is low and with grassland systems (Soussana et al., 2010). We need to improve tools to assess carbon sequestration at the farm scale, and more importantly, practice livestock farming methods to increase this sequestration (Hermansen and Kristensen, 2011). Second, some research has already been done on the evolution of plant species abundance within a stocking rate gradient and to assess the nutritive value of permanent pasture as well as plant and insect biodiversity. A model has been developed to explore the response to management practices favorable to biodiversity: this is possible by using more late-cut grasslands (Jouven and Baumont, 2008).

To summarize this section, animal production systems must preserve and enhance our environment rather than degrade it. It is clear from the above examples that livestock, and especially livestock used for beef production, can achieve this goal thanks to significant changes such as more extensive systems in grassland areas or more intensive sustainable and environmentally acceptable farming systems. Indeed, intensive and self-sufficient systems for low negative environmental impact are in a good position to achieve satisfactory economic results and have low sensitivity to price volatility in the current economic context (Mosnier et al., 2010).

### More Efficient and Robust Animals and Better Genetics

Of utmost importance is the urgency to keep (or even increase) competitiveness of animal production systems to maintain farms and farm-

ers with a sufficient degree of income, autonomy, and responsibility. The opening of a worldwide market of animal products has considerably changed the objectives of future European livestock systems. Producers should adapt themselves and their livestock systems to this new situation that has placed them in direct competition with faraway producers they do not know. A French study has shown that beef farmers have increased their competitiveness by more than 45% in the last 20 years (less than 10% due to genetics, nutrition, and breeding and about 40% due to an increase in herd size per farmer). Indeed, consequences of farm restructuring were much more important than the benefits of the progress in genetics and nutrition. Unfortunately, the average income for beef producers did not increase. In fact, it remained almost constant over 20 years despite a huge increase in financial aid from the Europe Community (Veysset et al., 2005 and personal communication). This asks the question whether it is still possible to increase the economic efficiency of production.

It is clear that the cost of feed has always represented a main part of the production cost of animal products, especially in the case of beef because the efficiency of metabolizable energy utilization for body gain above maintenance is low in ruminants (30 to 70%) compared with body gain in monogastrics (75 to 85%; Reid et al., 1980). At an animal level, meat production by ruminants is less efficient than by pigs or poultry, in part due to lower digestibility of forages compared with grains. Unfortunately, the cost of grain (which is used for fattening of cattle) has markedly increased lately, placing more emphasis on forage to maintain competitiveness (e.g., in the United States; Winslow, 2011). There is also a strong demand for natural feeding of ruminants (pastures) for improved animal health and welfare, limiting the use of antibiotics and other medication. This means animals will be more robust to be able to adapt to environmental challenges across seasons and across years (Friggens et al., 2010). At the same time, there is an increased competition for land use between the production of food for humans, the production of feed for farm animals, and other agricultural or nonagricultural use of land.

The efficiency of energy utilization in cattle is thus a determinant of the profitability of beef production (Reynolds et al., 2011). This again emphasizes the key role of gut efficiency management in production. Improving our knowledge of the regulation of ingestive and digestive processes will be a major scientific challenge that will allow adapting animal nutrition to constantly changing climatic and economic situations, while preserving metabolic efficiency. Variation between animals in feed conversion efficiency may have genetic components, allowing the selection of animals with greater efficiency. Although at least 90% of production is due to the environment (management, feed, animal health, and housing) and only a maximum of 10% due to the genetic ability of the animal, the recent sequencing of the cattle genome and the development of “omic” approaches have opened a new scientific era to better understand metabolism and hence improve nutrition and biological efficiency of cattle (Cassar-Malek et al., 2007) and humans (Hocquette et al., 2010). The analysis of the interaction between nutrition and genotype to produce animals with greater metabolic capacities to deal with new climatic constraints is another promising area of research. Knowledge of molecular aspects of digestion (which have received relatively little attention up to now) will be very important to understand how genetics and development of the animal affect the digestive process and to understand how animals use nutrients for different physiological functions (e.g., digestive function, growth, or reproduction).

In this context, the example of the beef chain in Australia may be useful to study. In Australia, farmers measure the cost of everything, especially the cost of animal feeds, and only use the best feed and the best genetics, with the best management system, and consequently, they never stop learning and are hence better educated than 30 years ago. In Australia, farmers have no government support, so they live or die by what they do (Kirton, 2011). We call that precision livestock farming, which should be developed as well in Europe. Some European countries have the advantage of feeding ruminants with grass at pasture and have been doing so for decades, whereas many Anglo-Saxon countries seem to be rediscovering this “natural beef.” From an economic point of view, a profitable beef production sector will continue to exist in Western Europe in marginal grass land areas with low costs for land and natural resources such as grass and with efficient short-term fattening procedures (Mihina et al., 2007). More generally, sources of feed for beef production should be primarily human-inedible materials such as forage from land unsuitable for growing crops, crop residues, or food- and fiber-processing by-products. This is already the case in developing countries such as China.

## The Management of Beef Quality

One major but classic issue is the need to control animal products for human satisfaction and nutrition from a quantitative point of view. Consumers are also asking for eating enjoyment and convenience. In addition, animal products (e.g., fresh meat or meat in ready meals) must provide essential elements for life and should be included in the human diet to meet but not exceed human needs, thus avoiding health problems that are well-developed in modern society (e.g., obesity, cardiovascular risk, and cancer; Scollan et al., 2011). The second objective is predominant in developed countries, whereas the first one is more important in developing countries in which a large part of human populations still do not have enough to eat. It is noteworthy that the hierarchy by consumers between

safety, efficiency, technological value, sensory and nutritional values of products, convenience, and other considerations (such as the carbon footprint) depends on the geographical location, with more emphasis on environmental and social concerns in Europe. Of course, these considerations (especially the quality criteria) have to be adapted with the development of ready-to-use products. Nowadays, some emphasis is placed on controlling variability in palatability in most developed countries. The controversial association between meat consumption and incidence of certain cancers needs clarification, but recent studies suggest this is of more importance for processed red meat products compared with intact meat (Scollan et al., 2011).

Regarding these challenges, the priority in our opinion should be a much greater integration of the beef supply chain with many more connections between actors (farmers, producers, abattoirs, wholesalers, and retailers). It should be noted that all disagreements within the beef supply chain (for instance between farmers and abattoirs, or between abattoirs and wholesalers) not only impair the overall efficiency of the process of quality guarantee for consumers, but also favor an unequal distribution of added values between actors. The consequence of consumer dissatisfaction is a progressive decrease in beef consumption per capita as observed in most developed countries. The consequence of disputes between actors of the beef supply chain is their incapacity to guarantee quality for consumers and to tell them the truth. We observe much contradictory or complex information given to consumers, or even a lack of or imprecise information, making it very difficult for consumers to find out what they need to know about beef.

The European beef product market is highly differentiated and very segmented because of the presence of many official quality signs under national or European labeling systems indicating high quality, environmental quality (organic farming), or quality linked to origin or provenance that coexist with many other distinctions, certified products, and brands. This wealth of schemes and labels creates a highly complex situation with a probable risk of information overload for consumers. Generally, consumers have a favorable *a priori* perception of products that carry some specific official quality signs (e.g., the organic farming label and the French quality sign Label Rouge), but they express a degree of misunderstanding on the real guarantees offered by them. Clearly, a high price for products with an official quality sign is a negative factor for purchases. In addition, increasing price sensitivity hampers products that carry an official quality sign, and younger consumers are less sensitive to the presence of an official quality sign (Tavoularis, 2008). These two observations are unfavorable for the further development of high-quality beef despite a demand by consumers and stakeholders in the food chain for quality guarantee systems. Safety and competitive prices have always been the main reasons driving food purchases in Europe and will continue to be so and to be of more importance than origin, brand, quality, or a combination of these.

All these observations do not raise specific scientific questions but mainly challenge the beef supply chain organization. One main challenge is how to apply our scientific know-how because it is presently not fully exploited (Scollan et al., 2011). Another challenge is to combine farming, genetics, biology, new genomic approaches (Hocquette et al., 2007, 2009), and traditional meat science to improve beef quality. Surely, these new challenges reinforce the need to conduct research in an industrial context. Indeed, scientific research should have an economic impact. In the case of red meat, we also have to work on its competitive advantages for human



health (important source of proteins, omega-3 fatty acids, and minerals such as iron and zinc). One objective would be to get nutritional value signals into the supply chain by marketing the key positive attributes of red meat. Unlike beef from Asia and America, beef from Europe is mostly lean especially when it is produced from late-maturing European beef breeds such as Charolais, Limousin, Belgian Blue, or Blonde d'Aquitaine (Hocquette et al., 2010), and we must promote this European specificity. Consumer purchase of animal products is essential in supporting the beef market, and therefore, the meat must be of high and consistent eating quality (Scollan et al., 2011). One very good example of such pragmatic and industry-oriented research in the beef quality area is the development of the Meat Standards Australia grading scheme to predict beef quality for consumers. This system is comprehensive, accurate, and scientifically supported, and most importantly, consumer-oriented. The Meat Standards Australia has identified the critical control points of beef palatability for individual muscles and for specific cooking methods and aging times. The scheme is the result of a high degree of cooperation between scientists and professionals from farm to plate and would introduce the much needed changes to support the preservation and the development of the beef sector. It could be very useful both scientifically and politically in Europe where the beef industry is much too conservative (Hocquette et al., 2011).

## Conclusions

Various scientific, strategic, and organizational aspects were evoked throughout the paper for different purposes and should be summarized here to define our views for the future of the beef supply chain.

Generally, recent developments in the fields of animal genetics, genomics (including genome sequencing and nutrigenomics), up to metabolomics provide important research approaches to investigate how genetic and nutritional variations regulate phenotypic variation in livestock, including the variation in sustainability traits (nutrient use efficiency, emissions, health, robustness). However, genomics alone is not a powerful enough tool and should be combined with phenomics, a modern word meaning high-throughput phenotyping, which became recently the bottleneck of modern biology. To address these issues with state-of-the-art concepts and technologies, a network of advanced and standardized phenotyping infrastructures, such as facilities for measuring greenhouse gas emissions or nutrient use efficiency, is required.

Despite these developments of basic research, the scientific questions should be targeted at practical issues. For example, the development of predictive approaches based on the systematic exploration of living organisms at different organizational levels and in different living conditions. This approach would provide more insight into whole animal response as a function of farming practices. Consequently, the introduction of modeling in biology is needed. Better knowledge of animal biology would help the development of precision livestock farming.

Focusing on efficiency of nutrition is also an essential challenge to limit the cost of using high-quality nutrient resources as animal feed and to reduce potentially harmful emissions (e.g. carbon, methane, and nitrogen). The new context will impose novel diet formulations for which digestive responses should be evaluated. The use of these concepts in animal feed requires knowledge of feed nutritional characteristics and an understanding of the response of the animal to specific nutrients (in terms of animal performance and product quality). The potential to maximize forage utilization by ruminants calls for an improvement of our

knowledge on forage intake and digestion, and also on carbon sequestration in soils. The publication of tables of feed value and feed evaluation systems have been major accomplishments, but the development of a European system of farm animal nutrition would be a key step toward a more efficient use of scientific resources adapted to European concerns (and may differ from those from other parts of the world). Furthermore, there is an increasing demand to evaluate feeds based on multiple criteria including nutrition, product quality, animal health and welfare, traceability, and general sustainability.

Whereas research priorities to mitigate climate change and optimize beef quality were perceived by most actors to be in direct conflict and mutually exclusive, it is more and more acknowledged that in farming, economic, social, and environmental performances are inseparable and are positively linked. Livestock do offer many benefits to ecosystems; notably they provide a means for managing grasslands while providing human beings with meat and dairy products. Society is also calling for a manifold re-greening of agricultural systems. Livestock farmers are therefore forced to adapt their farming systems if they hope to preserve their income and offer products geared to the market need and to societal demand for sound, environmentally friendly farming practices. Although raising livestock is justifiable ecologically, it does not necessarily mean that all ways of raising them are, or that ruminants are needed everywhere. Researchers, in concert with farmers, are asked to look some decades ahead and envision new ways of raising animals to amplify their benefits (Janzen, 2011). The challenge is to develop new concepts for efficient and sustainable animal farming and nutrition, especially in beef production for which the metabolic efficiency is low compared with milk production or meat production from monogastric animals. Beef should be produced using fewer natural resources in more sustainable livestock systems. This concept of sustainability should include environmental, economic, and social issues (Capper, 2011) and consider the interaction between land use, carbon footprints of foods, and expectations of consumers, instead of focusing only on productivity (Hermansen and Kristensen, 2011).

## Acknowledgments

The authors thank the members of the working groups on research strategy between INRA (French National Institute for Agricultural Research), SAC (Scottish Agricultural College), and WUR (Wageningen University and Research Centre) for helpful discussions. The INRA, WUR, and SAC have joined forces to formulate proposals for research on livestock farming at the European level.

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