1. Resource efficiency

The main challenge for the world is feeding 9 billion people within the carrying capacity of planet earth. The livestock sector is a valuable component of the bio-economy (in food and non-food functions). In the next decades, on the one hand we expect an increased demand for animal products, because of growth of the global human population, growing incomes and a shift in consumer behaviour worldwide, especially in the upcoming economies. On the other hand we face land scarcity, increasing greenhouse gas (GHG) emissions and limited resources, and it is to be expected that the availability of resources outside Europe for the European market (either as base (feed) or end products) will decrease or come available only at a much higher cost. This is a double challenge: the *efficiency* of the *use* of resources (e.g. energy, N, P, water, manure) must increase whilst at the same time improvements in the *way we produce and use* these resources must be made, so that the environmental footprints are reduced and the requirements for food production (e.g. health, welfare, social acceptance) are fulfilled. The importance of a European animal knowledge sector and ensuring the European animal production capacity can be made available for both the current and the future generation gains recognition.

To find ways to enhance food security in a sustainable way, we will need to pay greater attention to the efficient use of all associated resources. We require to minimise the need for resources, prevent avoidable losses ('wastes') and emissions, re-use unavoidable losses as feed wherever possible, use manure as a valuable residual and search for the optimal systems for the various species, and region-specific circumstances. This requires attention and improvements to the animal *as* a system, the animal *in* a system, and the system itself. Closing the nutrient cycles and re-use of valuable resources are central in this issue.

Animal production chains with increased resource efficiency enable a shift towards more sustainable intensification of food production and competitiveness of EU animal production chains. Socio-economic advantages are food security, sustainability, a reduction of climate change effects and realising a bio-economy. There will be improvements in biological and economic efficiency with reduced waste and emissions. Optimal solutions will recognise potential trade-offs between efficiency gains and health and welfare, or other important disadvantages losses. Identifying 'win-wins', or at least clarifying key trade-offs will enable better decision-making.

We will focus on four main opportunities for improving resource efficiency:

a) Efficient and robust animals.
b) Efficient feed chains.
c) Improving the use of residues in animal production.
d) Precision livestock farming.

1a. Efficient and robust animals ★★★

Background

One aspect of improving resource efficiency in the livestock sector, is to improve the animal *as* system. Improving the efficiency of animals involves reducing its 'feed conversion rate' (FCR: amount of feed needed to produce one unit of animal product) and thereby also contributing to reducing greenhousegas (GHG) emissions involved in livestock production[1]. The FCR has already significantly decreased in the past years by succesfull breeding strategies and more efficient feeding. Further improvements are to be expected by combined breeding and feeding efforts. Health (including fertility issues) and welfare aspects also play an crucial role in resource efficiency. Resource and nutrient efficiency in robust, healthy animals is higher than in animals with health problems. It is estimated by the World Organisation for Animal Health (OIE) that approximately 20% of animal production is lost due to unhealthy animals. Survival of juvenile fish (25-40%) is critical in aquacultures. Resource efficiency is thus also enhanced by reducing direct livestock losses, through, for example, clinical and sub-clinical disease, reproductive and metabolic failures, post-natal losses, 'failure to thrive' and premature culling or exposure to critical transition periods (such as weaning in pigs, onset of lactation in dairy cattle and the early post incubation period in poultry). These losses are not desirable both from an ethical, animal welfare, and a resource-use efficiency point of view.

Goal

Improve resource efficiency of animals by more efficient and robust animals that are more healthy, are more resilient, have an increased well-being, have a lower feed conversion rate.

How to achieve this

Until now, these aspects have been considered separately. To make progress, we propose an integrated approach to create more robust and efficient animals within systems, combining feeding strategies, genomics and health and welfare aspects.

- Appropriate phenotypes and appropriate indicator traits that reflect improved resource-use efficiency need to be identified. Selection using genetic, genomic, metabolomic and phenotypic information will allow gains in efficiency, (GHG) emissions, health and welfare. This includes the identification and implementation of welfare indicators that are animal-centred. The combined use of genetic, genomic, metabolomic and phenotypic information is innovative and provide a profound knowledge and holistic understanding of improving resource efficiency - e.g. feed efficiency - in animal production combined with other gains.
- Improved breeding programmes for robust animals should include systems of feedback of information from the production chain into the breeding programmes through novel means such as automated data collection and genetic linking through genomics tools. Trade-offs between environmental, economic, health and welfare must be made visible
- Identification of new species for European aquaculture based on perspectives for domestication of species with high market potential and high resource efficiency.
- Feeding management and farming systems can substantial contribute to robustness and resilience of animals. E.g. systems that promote early feed intake after incubation of chickens has shown to have long lasting positive effects on health, welfare and performance. A systematic approach to identify key factors that hamper robustness during critical transition periods is needed to find new approaches to cope with these transitions.

Expected impact

More efficient and robust animals contribute to resource efficiency by reducing resource use and resource loss.

[1] Approximately 5% of livestock's contribution to GHG emission originate from feed production.

1b. Efficient feed chains ★★★

Background

Animal feeding plays an important role in livestock production systems. Feeds and feeding are means to influence animal performance, production costs, product quality, environmental impact, animal health and welfare, and food security. Besides selection for improved genotypes that increase efficiency of resource-use within animals (see 1a), more efficient feed chains are needed to ensure future resource efficient livestock agriculture. This requires that a larger fraction of the feeds produced is converted into human edible food and that losses in the feed and livestock industry are minimised. Novel in this topic are the opportunities that precision feeding has to offer for increasing feed efficiency by adapting feed needs to individual animals.

Efficient feed chains also involve alternative feed resources, while not competing with food for humans or having a large impact on land-use change. This covers utilisation of by products of the food industry, finding alternative crops, better use of local resources. This also involves socio-economic aspects as new business models and management systems are needed for specific production systems which allow for the demand for feed of individual genotypes and allow for variations in feed supply. It might be clear that this topic does not stand on its own: robust and efficient animals are required that fit within feed chains to be able to fully benefit from the opportunities for resource efficiency. For Europe the development of alternative protein supply strategies that minimise reliance on imports (i.e. soybean and fishmeal) is also of strategic importance (this is further discussed in section 2c).

Goal

Create new opportunities to improve the efficiency of feed chains by optimising the quantity of feed available for the animal, reducing losses, better use of local resources and creating new feed chains of alternative feed resources and by-products of the food chain, thereby reducing wastes.

How to achieve this

Improving efficiency in feed chains requires an integrated approach that combines nutrition, genetics, supply chain management, geographical knowledge and socio-economic aspects. We propose to focus on:

- Research on the interaction between genetics and nutrition, and exploiting the differences between the individual animals in 'feed efficiency' to match the input to needs as these change with time (and the animal's physiological state), will generate new possibilities for improved feed utilisation. New practical feeding systems should be developed that enable precision management for feed use efficiency (so called 'precision feeding') without unwarranted costs. Development of innovative sensors and intelligent models for monitoring and management of nutrient use (in)efficiencies at animal level (also for animals in groups (herds, sea cages).
- Exploring better use of organic waste streams and unused by-products of food production chains through development of novel and existing technologies. This includes specific processing technologies and technological treatments for meeting the EU feed safety requirements (e.g. for food products no longer destined for food use); to research the response and possible efficiency effects on animal performance to these products (see also 1d).
- The aquaculture development of carnivorous fish species requires increased utilisation of still emerging vegetable feed sources to limit impact of fisheries on wild fish stocks. However, vegetable oils can contain specific toxins and bioactive compounds and vegetable protein can contain specific toxins and anti-nutritional compounds that may affect feed efficiency, processing yields and fish health and welfare during the whole life-cycle, as well as the quality of the product. Research is needed to explore the potential of selective breeding of aquaculture species and genomic information applied to extended phenotypes in various environments and rearing systems to develop breeding programmes that maximise the utilization of vegetable ingredients, while maintaining high levels of product quality and fish health and welfare.

- Current feeding systems are based on the concept of ‘feed values’ and ‘nutritional requirements’ but ignore that the animal responds to the nutrient supply in a dynamic way, and that this response needs to be considered in a multi-facetted manner (e.g., animal performance, emissions, tissue and product composition, health and behaviour). New and innovative models on the nutrition of farm animals, including dynamics and kinetics in digestion and metabolism are expected to significantly contribute to a further reduction of energy and nutrient losses, better quality of animal product and better use of alternative resources. Moreover, there is now a need and willingness to work towards a more harmonised system of animal nutrition in Europe. Although similar concepts have been adopted in many of these systems, terminologies and methods of determination vary greatly from country to country. This makes comparison and cross-use of information very difficult particularly by the feed industry, which is increasingly pan European.
- With ruminants, research should be directed on an integrated approach of identifying the best genetic potential for low energy loss and simultaneously developing diets that lower energy losses as methane. This approach will result in combined management strategies with genetic selection for improving efficiency of nutrient use that will also lower the incidence of metabolic diseases and increase fertility (including reproductive failures, post-natal losses and ‘failure to thrive’).
- A model, based on consequential LCA, needs to be developed to determine the trade-offs in environment-socio-economic impact when decisions are made concerning the use of by-products and alternative resources.

Included in research on new products, technologies and strategies should be the development and testing of business models.

Expected impact

The life cycle impact of dairy, meat, egg and fish production will greatly improve, whilst recognising the animal production potential and management in a holistic way. Increased resource efficiency by improved feeding management systems and optimised feed chains, including the delivery of the best strategies to develop alternative feed resources; reduced protein imports into Europe, and reduced competition between feed and food production. Key enabling technological developments will make Europe frontrunner in re use of by products and protein rich resources for feed.

1c. Improving the use of residues in animal production ★

Background

Manure is often seen as a residual burden rather than a valuable resource. In areas with intensive animal production effective manure management can improve resource efficiency by turning manure into a valuable resource. Especially the re-use of N (replacing artificial fertilisers with their high associated energy costs), and of P (which is a first limiting resource for all plant production and which is in very limited supply globally) offer tremendous opportunities for closing nutrient cycle, increase resource efficiency and restrict pollution and eutrophication of ground waters. Manure (especially solid manure) is a unique source of carbon for soils. In addition, integrated manure management offers new solutions for on farm energy production since the price of fossil fuels is expected to increase.

Goals

More efficient recovery and recycling of food, feed, water and animal waste, including P losses and N emission reduction. Reduced energy costs across animal farming.

How to achieve this

To make progress, there is a necessity for a holistic approach where system analysis is used to assess the total effects of different practices. Besides technological progress, socio-economic studies are needed to create sound business models and organisational models for manure treatment. We propose to focus on:

- Assess the efficiency of different products from manure (from pure minerals to organic matter fractions) for closing the mineral loops. Explore new techniques like refining manure to valorise the individual components of manure and treatments leading to the production of normalised fertilisers that can be exported from high density livestock territories to arable land.
- Assess scale and local systems organisation to improve the efficiency of anaerobic fermentation systems of manure and other food/farm wastes. This includes socio-economic studies and developing business models that can be adapted to regional situations and evaluate the geographic scale that is needed for optimal effects in nutrient dispersion. Ideally this also includes implementation and strategies to upscale successful business models to wider application.
- Assess the efficient recycling of nutrients in manure and the effects of feeding management on manure quality. Innovations have been developed to better handle nitrogen losses, especially NH_3, in buildings, during storage and manuring. It remains necessary to control the entire storage and manuring chain to preserve nitrogen: interactions between different steps in management are thus important and to have a better knowledge of the bioavailability of nitrogen from manure.
- Assess the potential risks for re-circulating infectious agents and evaluate different disinfection and mitigation strategies in order to provide a sustainable use of residual resources.
- Development of energy efficient recirculation systems for aquaculture enabling full control of water and effluent management.
- Development of Integrated Multi-Trophic Aquacultures (IMTA) for combining fish farming with the production of shellfish and seaweed to re-utilise feed residuals.

Expected impact

New unique ways of efficient resource-use at system level that reduce wastes in the feed and food chain; improvements in the re-use of nutrients in manure, and of energy stored in carbon connections, less negative environmental impact. Potential addition of high value added products from manure for other industries.

1d. Precision livestock farming ★★

Background

Sensor-driven livestock technology offers potential solutions. Precision Livestock Farming (PLF) develops management tools aimed at continuous automatic monitoring of animal production, environment, health and welfare in real-time. Sensor technology integrated in monitoring systems will allow farmers to follow the animal's status, to observe their performance or detect diseases at an early stage and to monitor the environment. Today sensors can detect irregularities in such things as physiological measures (e.g. in milk, body temperature), drinking and feeding patterns (to detect disease), social behaviours (to detect oestrus), activity (to detect disturbances in climate control), and locomotion (to detect lameness) are needed to improve the control of unwanted behaviours, and to improve the precision of management for the delivery of quality products, health, welfare and environmental outputs. With the help of this technology, farmers and veterinarians can continuously, and automatically, collect and manage the information needed to manage together the multi-dimensional component of the individual and livestock and assure citizens that livestock production is safe, humane and environmentally sustainable while reducing labour load. ICT technology can help, for example, to measure individual differences for management (e.g. of resource use) or phenotyping in support of new breeding goals.

Goal

To develop and implement future options for innovation in livestock systems that will make Europe's livestock systems more efficient and sustainable. To achieve integration of knowledge between biological, veterinarian, social, economic, engineering and ICT scientists. To combine research and development with product and service development by matching academic and industrial communities.

How to achieve this

- Better support tools that combine information on individual animals with ration formulation and management routines should be developed to achieve optimal productivity and simultaneously avoid wastage. Physiological models must be developed to better interpret and use sensors data. The objective is to convert data from these tools into useful information and decision support systems for farmers and service providers like veterinarians to better manage the individual animals and the herd both on a short term basis (early detection of infections or metabolic disorders, precise feeding considering animal responses, regulation of environmental condition in building) and a medium term (improving the practices from clear historical information). This requires the development of mathematical decision support modelling (e.g. data mining and artificial intelligence), (wireless) sensor technology, ICT-infrastructure (web based, databases), standardisation (e.g. RFID) and user-centric design methods to evaluate the interest of cumulating data from different origins (biological, behavioural) and to improve the quality of the diagnosis and support. Research will focus on biological models and decision support tools and industry (including innovative SME) will consider hardware structure.
- Sensor information will also provide useful information for high speed automated phenotyping technologies which are needed to be further developed and applied to enable real-time management and to provide data for the delivery of new breeding goals.
- The choices for the farmer will touch the socio, economic and technological integration and discussions and should be addressed in the Horizon2020 programme.

Expected impact

New technological developments as described above will make the management of farmers and service providers more efficient, and allow for farming practices that reduce wastes, reduce emissions, give early detection of irregularities and improve welfare and health. However, the biggest social impact is that farmers will be supported in giving care to individual animals that are part of groups, and taking care of the circumstances in which these groups have to function. This will be a system innovation. Further development of precision livestock farming will make Europe's agricultural sector an example for the world.