The Role of Animal Nutrition in Sustainable and Healthy Food Systems

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The requirement of humans for protein represents on average 10–35% of the daily caloric intake. According to the Dietary Reference Intakes (DRIs) issued by the Institute of Medicine of the US Food and Nutrition Board,[1] adults need to eat about 60 grams of protein per day. The typical diet of the Western world contains more protein than is strictly necessary, while in developing countries and emerging economies, the supply of high-quality protein is still insufficient.

Protein is mainly found in meats from poultry, pork and beef, in fish, eggs and dairy products (cheese and milk), but also in vegetable sources such as legumes (soya, beans), grains, nuts and seeds, and also in certain vegetables. Protein that comes from animal sources is in general nutritionally more complete, because it contains the essential amino acids in a more adequate pattern than is the case with plant proteins.

Current production of animal-derived protein

Poultry meat and eggs

Several avian species have been domesticated for the production of food, the most important being broiler chickens and laying hens, which are currently kept all over the globe for the production of high-quality meat and eggs. Poultry meat is relatively cheap, is considered to be a healthy food, and is well accepted, as there are no restrictions on its consumption by major religions or local traditions. Poultry meat production is therefore constantly on the increase, and will soon become the most popular animal-derived food worldwide.[5,6]

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Today's laying hens can produce more than 280 eggs per production cycle. Eggs are appreciated as being among the most nutritious foods. Furthermore, eggs represent a perfect vehicle for the transfer of high-quality nutrients, such as vitamins, to human subjects. Eggs can be fortified via the dietary route with α-tocopherol and β-carotene, two antioxidants which are associated with health benefits for humans.[2,3] Alternatively, multiple-enriched eggs can be obtained by feeding laying hens with linseed, long-chain essential fatty acids, minerals, vitamins and lutein, resulting in eggs of greater nutritional value that contain several times the usual levels of omega-3 fatty acids, more of the vitamins A, E and D_3, the B-vitamins B_2, B_{12}, folic acid, pantothenic acid, more lutein and zeaxanthin, and more phosphorus, iodine and selenium.[4]

Pork production

Today's swine industry is still less concentrated and less integrated than the poultry industry, and the production of growing

Broiler chicks – chickens are the most popular of the domesticated avian species.

Laying hens – capable of producing more than 280 eggs per production cycle.

and fattening pigs is less efficient than that of broilers. Pig meat is not accepted by certain religious communities such as Muslims, and accordingly this industry is not present in several large countries of the Middle East and Asia. Nevertheless, pork is the most widely consumed meat in the world.

Ruminants: Beef cattle and dairy cows

Although meat produced via beef cattle is the least efficient of all animal protein types, it is ecologically important, as it utilizes a vegetable biomass which otherwise would be wasted to yield high-quality protein for human consumption. Ruminants can digest ligno-cellulosic material in their rumen; this process results in protein (bacterial biomass) and volatile fatty acids (energy) for the host animal.

In most countries, the dairy industry uses cattle breeds which were genetically selected for high milk production over many generations. Dairy cows in highly developed production systems deliver on average only 2.5 lactation cycles, which is seen as a dissipation of resources, considering the long investment required to bring a calf/heifer to sexual maturity. Frequent health issues in dairy cattle, which result in the culling of cows, are fertility problems, lameness due to serious claw disorders, and chronic mastitis.

Aquaculture

Since levels of wild fishing are stagnating, aquaculture has developed exponentially in order to satisfy the growing demand for this type of food. Farming of aquatic species represents the most diverse food-producing industry, ranging from invertebrates such as mollusks and crustaceans and a large variety of fish to reptiles such as crocodiles. The animals belong either to freshwater or marine species, and rearing takes place in tanks, ponds, rivers, lakes and the ocean.

A special requirement of carnivorous fish species such as salmonids is that they need fishmeal for fast growth, which is produced in enormous quantities via the processing of wild-caught fish. As such farming conditions might not be sustainable in the future, research efforts are directed towards diet compositions which allow using more vegetable protein, e.g. soya. Moreover, there are indications that aquaculture could use insect protein, whose amino acid composition is largely similar to that of fishmeal.

> "Aquaculture has developed exponentially to make up for stagnating levels in wild fishing"

Global demand and future requirements

The world average meat consumption is 41.9 kg per person per year (data from 2009[5]). However there is a considerable difference between the developed and developing world. Although meat consumption is tending to stagnate in highly developed societies, a strong increase is expected in emerging economies due to urbanization and growing affluence of the people in these countries.

According to FAO,[6] total global meat production reached 296.1 million tons (mT) in 2013, of which pork had the largest share with 109.4 mT, followed by poultry with 99.1 mT and beef with

Pigs – pork is the most widely consumed meat worldwide.

Dairy cows – selected for high milk production over many generations

67.8 mT. The highest per annum growth rate between 2000 and 2010 was observed in poultry (4.3%), followed by pork (2.2%). It can therefore be anticipated that in a few years' time, poultry meat production will overtake that of pork. Total egg production reached 69.1 mT in 2010 with a growth rate of 2.5% over the last 10 years. Milk production is comparatively low at 0.72 mT on a global scale. There is still more fish coming from capture (88.6 mT) than from aquaculture (59.9 mT), but fish availability from fishing is on the decline in most global regions.

According to OECD[7] (2014), global meat production will increase by 19% between 2014 and 2023, with the highest share of this increase in poultry (34.0%) and in swine (23.5%). If this strong growth were to persist or even accelerate, meat production might need to be doubled by the year 2050, when the world population is predicted to reach 9 billion.

"According to OECD, global meat production will increase by 19% between 2014 and 2023"

Opportunities to increase meat production

Doubling animal-derived protein production in a sustainable way represents an enormous challenge for this industry. It means finding the land for placing the farms for the additional animals, but also increasing the production of raw materials for feed, particularly the main ingredients such as corn, cereals and soybean. For the transport of both feed and animals, adequate carriage capacity and infrastructure will be needed, and new processing plants will have to be constructed. Furthermore, the additional waste (manure, slurry, gases, slaughter offal) will need to be handled in a way that optimally protects the environment (soil, water, air).

Breeding

Increased efficiency in meat production must accompany the overall rise in livestock production. In poultry, growth and feed conversion rates – being the ratio of amount of feed in kg per kg live weight (typically 1.5 to 1.8) – have already been massively improved, and this development must be pursued. For swine, there seems to be considerable potential for better performance, but progress is slower on this front. Efforts to increase productivity are ongoing in beef cattle and in dairy cows as well. Although already rather efficient, aquaculture could still increase overall performance levels by improving the flesh yield in fish.

Nutrition

For maximum production efficiency nutrition, both in terms of macronutrients and of micronutrients such as vitamins, meat production needs to be optimized. High-yielding breeds are delicate hybrids, and their nutrition must be carefully balanced in

order to exploit their full genetic potential. Since supplemental vitamins, which are not instantly utilized by the metabolism, are deposited in meat, eggs or transferred into the milk, they eventually improve the nutritional value of these end-products for the consumer.

Feed utilization

To improve the sustainability of animal-derived protein production, the limited resources of feedstocks must be exploited to the maximum. For this reason, feed enzymes are commonly used in monogastric animals (poultry, swine) to improve the digestibility of nutrients. Carbohydrases with different specific activities can degrade fibrous material in cereals and thereby make energy available to the host which otherwise would be wasted. Proteases improve the digestibility of protein, which is the most expensive feed ingredient and of which the supply might become limited in the future. Finally, phytases release inorganic phosphorous (P) from plant-bound phytate, which could not be utilized by monogastric animals in former times. By using such products, less non-digested potentially pollutant P is excreted by the animal.

Alternative feed ingredients

Another necessity for keeping a higher production rate sustainable is to find alternative feed ingredients, since the production of common crops might not be increased to the necessary extent, and as the main feedstuffs (corn, cereals, soybean) compete directly with human consumption. There are tropical raw materials available which could serve this purpose.[8]

Besides vegetable sources of protein, insects have recently been considered as potential feed ingredients for livestock and aquaculture production. The larvae of insects contain up to 60% of high-quality protein and the content of indigestible chitin is lower than in the adult stage. Insects can be grown on bio-waste from the food processing industry or from households, and certain species could even utilize ligno-cellulosic biomass. Insects have a more efficient feed conversion capacity than any other farmed animal, and the requirements for management and husbandry are rather low.

> “Insects have recently been considered as potential feed ingredients for livestock and aquaculture production”

Longevity of high-yielding livestock animals

Under production conditions, farm animals are prone to fatal diseases of various origins. Furthermore, high productivity is rapidly exhausting the metabolic resources of long-lived animal categories (laying/breeder hens, breeding sows, dairy cows) and reduces their life expectancy. A prolongation of their lifespan would contribute substantially to an improvement of the production efficacy, with more eggs or day-old chicks, more piglets, and more milk.

The elimination of antibiotics

A special challenge of meat production is the elimination of antibiotics from animal farming. For a long time, antibiotic growth promotors (AGPs) were added to the feed of livestock for the prevention of infectious diseases. Since certain of these products are structurally related to antibiotics used in human medicine, the considerable risk of inducing cross-resistance in life-threatening pathogens has been recognized. Consequently the prophylactic use of AGPs has been banned in Europe, but is still allowed in the rest of the world. As alternatives to AGPs so-called “Eubiotics” – which have the ability to beneficially modulate the gut microflora – are being developed. Pre- and probiotics, organic acids and essential oils have the potential to foster adequate gut health. Yet the therapeutic use of antibiotics for treating animal diseases is currently not under scrutiny, although the approval for certain products from human medicine has been revoked.

Environmental considerations

Facing the massive increase in demand for animal-derived food and consequently the enormous expansion of animal husbandry, the environmental emissions from this industry must be given special attention.[9] The first concern should be the sustainable

Salmon – a carnivorous fish species that needs fishmeal for fast growth when farmed

disposal of manure. Although animal excreta and slurry are convenient fertilizers, grasslands and croplands should not be oversupplied with nutrients which cannot be bound by the soil matrix and therefore would leak out into rivers and lakes, causing eutrophication of the water resources. Furthermore, trace elements such as zinc, copper and cobalt, which are essential for animal performance, can accumulate in the soil and thereby create damage to the growing crops. Making animal-derived protein production more efficient should result in less excreta per unit of edible product. But considering the expected expansion of production, novel concepts for processing the manure and potentially extracting valuable fractions from this material for re-use are urgently required.

Gas emissions of carbon dioxide, ammonia and methane, which contribute to the greenhouse effect and thus aggravate the global warming problem, should not be allowed to increase.[10] For this environmental issue, a few feed additives are available on the market, but none of them currently seems sufficiently efficacious to allow anticipated levels of production growth in poultry and swine with neutral or shrinking emissions. Methane from enteric fermentation in ruminants represents the single largest source of anthropogenic origin. For this segment, a feed additive is under development which has the potential to reduce methane emissions by at least 30%.[11] Nevertheless, more research and development in this field is urgently needed.

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