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Global Challenges for A Sustainable Production of Food of Animal Origin

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Introduction

Milk, meat, eggs, fish and further food (e.g. insects) are considered as food of animal origin. They are rich in essential amino acids and important trace nutrients such as minerals (e.g. Ca, P, Fe, I, Se etc.) and vitamins (A, E, B_{12} and further B-vitamins). Food of animal origin contribute to meet human requirements and have large significance, mainly. for children and juveniles as well as for pregnant and lactating women [1] and they may stabilize human nutrition. Due to the increase of global population, the higher income in many countries and to overcome present under- and malnutrition (mainly in developing countries), an increase of animal-source protein is expected.

On the other side – the production of food of animal origin needs considerable amounts of limited resources, such as arable land [2], water [3], fuel, some minerals (e.g. P) and causes emissions with possible relevance for climate changes (e.g. methane – CH_4; nitrous oxid – N_2O).

These developments raise concerns about the sustainability and the environmental impact of animal agriculture. That means, food security and optimal human nutrition under consideration of limited resources and increased emissions can be considered as large challenges for all those dealing with feed and food production and nutrition [4]. The objective of the contribution is to analyse the sustainability of food production of animal origin and to conclude for further challenges.

What means Sustainability?

The large need of wood in Europe in the middle age resulted in an overexploitation of forests. During this time forest scientists formulated on the base of their own experiences the so-called principle of sustainability in forestry: "The most important objective of science/management is the conservation and cultivation of forest that a sustainable utilization (not more harvest than growing up) can follow that the country may exist in the future" [5].

Later, the "Club of Rome" [6,7] introduced the terms "Sustainability and sustainable development" in the "political language". Environmental objectives were combined with social-economic objectives to arrive stable societies and a balance between economy, ecology and social/ethical aspects (Figure 1). Later, philosophers and natural scientists of various disciplines studied and analysed present global developments and concluded that the balance between Planet (global resources and emissions) – People (social and ethical aspects of population all over the world) – and Profit (economic aspects of making money) in the so-called 3P-concept [8-10] is an important prerequisite for a sustainable life and development on the earth. The balance between these four elements (Figure 1) should be considered as a fundament of sustainable food production.

A local feed production as base for a sustainable animal husbandry should be developed instead of land grabbing, import of food (e.g. wings, heads and other co-products of chickens, dried skimmed milk) and other activities of the so-called aid in developing countries. All activities should be assessed under aspects of sustainability for the following generations.

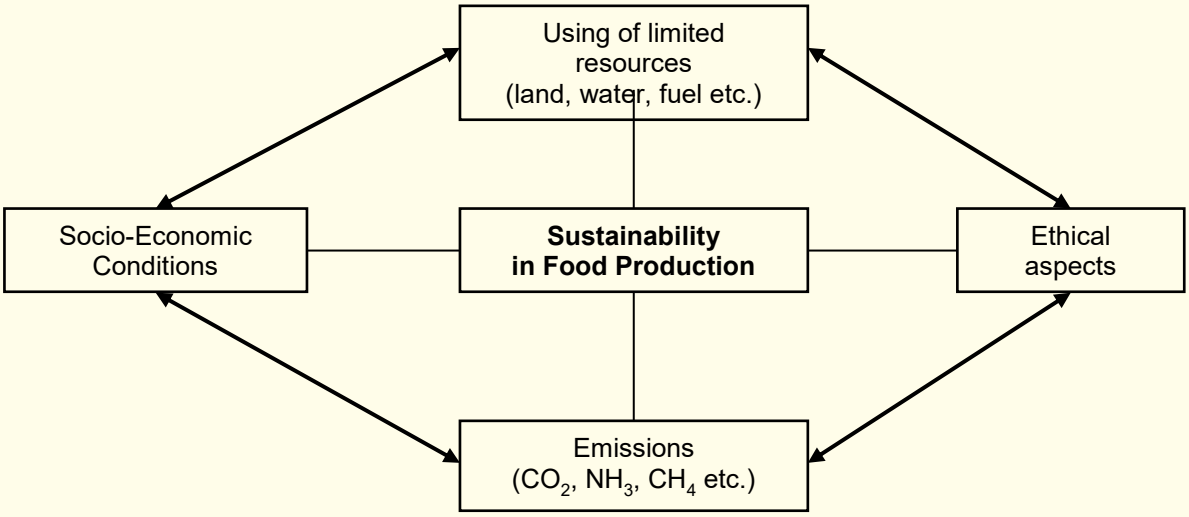

Figure 1: *Sustainability as balance between using of limited natural resources, emissions, socio-economic and ethical conditions to produce food of animal origin [11].*

Present Situation

Table 1 summarizes for important land animals as protein sources the protein yields as well as land, water and carbon footprints (CF) in dependence on animal species, performance, dry matter intake and concentrate portion in the diet.

Arable land can be considered as one of the most important global limiting factors. Only a small portion of the global surface (about 13.4 billion ha) is available as arable land (about 1.5 billion ha). In consequence of the limited area of arable land and the increase of population, the arable land per inhabitant decreased from about 0.45 (1960) to about 0.25 (2010) and will going to decrease to less than 0.20 ha per inhabitant after 2020. Arable land use per unit of animal product or protein of animal origin depends mainly on animal species, plant and animal yields (Table 1) as well as the using of grassland and the portion of co-products (feed from food and fuel production) in animal rations. There is only a small or no competition to food between animal and human nutrition, if feeds with low portions of human edible fractions [12,13] are fed. The variation in Land-Footprints (LP; Table 1) resulted from the portion of concentrate and co-products in the diets and the plant yields.

The Water (WF) and Carbon-FP vary between protein sources and the animal performances (Table 1). In general, the higher the animal performances – the lower the WF and CF. In the case of CF`s there are large differences between ruminants (cows and bulls) and non-ruminants (pigs and poultry) because of the methane synthesis in the rumen of ruminants in conjunction with the high green-house-gas potential of methane (23 x CO_2).

Protein source (Body mass)	Performance (per day)	Dry matter intake (kg/day)	Concentrate of diet (%)	Edible protein yield (g/day)	Land-FP (m^2/kg edible protein)[3]	Water FP[4] (m^3/kg edible protein)	Carbon-FP (kg CO_{2eq}/kg edible protein)
Dairy cow (650 kg)	5 kg (milk)	10	5	163	33 - 135	16.0	50
	10 kg	12	10	323	22 - 88	10.9	30
	20 kg	16	25	646	15 - 68	10.6	16
	40 kg	25	50	1292	15 - 70	12.3[5]	12
Beef cattle (350 kg)	500 g ADG[1]	6.5	5	48	72 - 295	34.0	110
	1 000 g	7.0	15	95	41 - 180	24.7	55
	1 500 g	7.5	30	143	35 - 155	24.5	35
Growing/ fattening pig (80 kg)	500 g ADG[1]	1.8	80	45	36 - 176	35.8	16
	700 g	2.0	90	63	30 - 148	31.3	12
	1 000 g	2.2	100	90	24 - 120	26.1	9
Broiler (1.5 kg)	20 g ADG[1]	0.06	85	2.4	15 - 80	20.0	5
	40 g	0.07	90	4.8	14 - 68	14.4	4
	60 g	0.08	100	7.2	12 - 60	11.8	3
Laying hen (1.8 kg)	50 % LP[2]	0.10	80	3.4	28 - 122	26.5	7
	70 %	0.11	90	4.8	26 - 105	22.5	5
	90 %	0.12	100	6.2	20 - 95	20.8	3

Table 1: *Influence of species, categories, performances and feeding on outputs of some land animals [2].*

1) Average Daily weight Gain, 2) Laying performance; 3) Depending on yields of grassland and arable land as well of feed by co-products; 4) Calculated on the base of data by Mekonnen and Hoekstra [14]

5) Higher water need for concentrate increases WF

Challenges and Alternatives

The following topics should be considered as important challenges for a sustainable food production:

Plant breeding

Plant breeding can be considered as the starting point of the human food chain. Traditional breeding as well as "green" biotechnology may result in plants with high and stable yields, resistance against biotic and abiotic stressors and with a low content of undesirable substances [15]. Special attention should be given to the adaption of plants to the expected climate change [16]. General challenges for plant breeders are the production of high amounts of digestible biomass under consideration of unlimited (e.g. N_2; CO_2; sun energy, genetic pool) and limited (agricultural area, water, fuel, some minerals) natural resources [17].

Animal breeding

The global numbers of livestock animals used in animal husbandry has been estimated to be about 1.8 billion large ruminants (e.g. cattle, buffaloes, camels), 2.4 billion small ruminants (sheep and goats), nearly one billion of pigs and about 20 billion of poultry [18]. Higher animal performance and a reduction of the large animal numbers would be a substantial contribution for a more efficient production of food of animal origin (see Table 1). Animal breeding, improved animal health, better animal feeding and management may contribute to a more efficient animal production [19].

Use of feeds which do not compete with human nutrition

Grassland and co-products from agriculture, food and biofuel industry do not compete with arable land and further limited resources in human nutrition. Many papers and textbooks are available to describe the nutritive value of co-products for animal nutrition and should not discussed further here.

Further alternatives

In addition to plant and animal breeding and the use of grassland and co-products, there are further alternatives/challenges and new developments to overcome food deficiency, to guarantee food security and to produce food in a sustainable way, such as:

- Reduction of feed and food losses along the whole food chain [20]
- Changing of eating patterns (lower consumption of food of animal origin with high FP (see Table 1; [21])
- "Simulated" food on the base of plant products (cereals, legumes, plant leaves etc.; [22])
- Insects as protein source [23]
- Using of single cell proteins (e.g. microbes, algae etc.; [24])
- Cultured "Lab Grown" (cell cultured, synthetic or clean) meat [25].

Conclusion

More (food) for more (people) with less (resources and emissions) can be considered as the large challenge for all those working along the food chain.

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