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Effects of production potential, system of production on environmental footprint in different animal species

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ABSTRACT

Growing world population and increasing purchasing power increases the world consumption of animal products. To consider aspects of more efficient utilization of basic resources as water, feed etc. requires more attention, combined with the growing concern regarding, the environmental footprint, per unit product and its interrelationship with the production potential of the animal populations, and systems of production. In latter context research results are reviewed. Poultry, pig, sheep dairy cattle and beef production examples are presented, showing clearly that more productive populations and systems are characterized by significantly reduced environmental footprint per unit product compared to less efficient ones. Water utilization as an example was improved due to genetic improvement in broilers and turkeys by 250–300% in breast fillet meat production in the last 30 years. Dairy production system developments in the USA between 1944 and 2007 reduced the environmental footprint, and reduced the necessary feed production area dramatically among species the more prolific ones have a competitive edge if production is based on feeds produced by the arable agricultural sector.
(Keywords: environmental footprint, unit product, level of production, systems of production, poultry, pig, cattle)

INTRODUCTION

Growing population numbers and increasing per capita incomes in many parts of the World impose an ever growing demand for human food and animal feed supply. The bio energy production is a new serious competitor. The natural basic resources, land available and soil quality is diminishing and deteriorating in several areas of the World. Ground water levels shrink, the border conditions for irrigation worsen both in several developed (USA, Australia etc.) and in developing countries (China, India etc.) (*Diamond,* 2007). Marine – and to a lesser extent – freshwater living fish populations have been dangerously reduced due to extreme overfishing. Fish represents a vital and is the sole animal protein source for more than 1.2 billion people in the developing world, and constitutes a valuable part of the healthy human diet in developed countries (*Diamond,* 2007). Marine and freshwater fish production waits for a real new revolution: development of novel artificial breeding systems, establishment of large protected marine and freshwater ecosystems, innovative fishing technologies, strictly and efficiently enhancing a much more sustainable type of approach regarding the maintenance of fish populations both quantitatively and qualitatively worldwide (*Horn,* 2007). Climate change will probably negatively influence plant agriculture both quantitatively and qualitatively. Risk factors will increase as a large number of reliable publications call our attention to the problem.

Growing per capita income linearly increases consumption of foodstuffs of animal origin, most significantly meat. Below 1500 US $ annual family income the food is of plant origin. Above this income level people begin to consume also food items of animal origin (*Roppa,* 2007). The switch from a vegetarian diet to animal products requires a 4 to 12 fold plant biomass production – depending on the type of animal product – due to transformation losses. Animal agriculture faces great changes and challenges.

Water utilization and production potential

In the context of the global climate change, it seems more and more important to consider water utilization efficiency per unit product in animal agriculture. In Kaposvár several evaluations were conducted in the last years to compare water utilization efficiency with numerous genotypes characterized by significantly different performance levels. In chickens the 1978-, 1998- and 2008-type tipical broilers were compared regarding water utilization to produce 1 kg of breast fillet meat.

The 1978-type broiler needed 40 l drinking water, and 20,000 l of precipitation water to produce the feed for 1 kg breast fillet meat production. Due to genetic change in 30 years in 2008, broilers needed only 14 l drinking water and 7000 l precipitation water for the same realized production. Roughly at present only one third of water is necessary to produce the same amount of breast meat fillet as 30 year ago (*Horn,* 2005; 2008). Comparing Turkey strains representing 1967 and 1999 types, and reared under identical environmental and feeding conditions (*Herendy et al.,* 2004) it was found that 1967 type bronze turkeys needed 50.6 drinking water, and 25,300 l of precipitation water (feed production) to produce 1 kg of breast fillet meat, whereas the 1999 type turkey needed only 21 l drinking water, and 20,500 l of precipitation water for the same product (*Horn,* 2007).

Calculations showed that water utilization of dairy cows per unit milk production diminished by 1.6 l regarding drinking water, and is reduced by 427 l considering the water (precipitation) quantity needed for feed production if milk production rises from 4000 to 12000 kg/year cow. Increased production from 4000 to 8000 litres of milk saves 1.1 l drinking water and 312 litres of precipitation water for 1 kg milk (FCM) produced (*Babinszky and Horn*, 2005), cit. *Horn* (2005, 2007)

Improvement in genetic potential significantly improves water utilization efficiency per unit product. In monogastrics (meat type poultry) the correlation between levels of performance is very close to linearity with water usage efficiency. In milk production this relationship is different, the higher the level of the cows' genetic potential, further gains yield smaller and smaller improvements in water efficiency to produce unit amount of milk.

The environmental footprint and animal production

It is of great importance in the future to consider the differences existing between species, genotypes within species and systems of production related the environmental footprint per unit of product destined for consumption.

The large scale evaluations published by *Williams et al.* (2006), show that between different livestock sectors very large differences exist in inputs and several components deteriorating the quality of the environment in a complex manner (glass house effect, eutrophycation potential, pesticides use, land use) determining the environmental footprint (*Table 1*).

Table 1

The main burdens on environment and resources used in animal production per tonne of meat, per tonne of eggs (20,000) per tonne of milk dry matter (10 m^3 milk)

Impacts and resources	Poultry meat	Eggs	Pork meat	Beef	Milk	Sheep meat
Primary energy used, GJ	12	14	17	28	25	23
Global warming potential 100 year time scale, CO_2 t	4.6	5.5	6.4	16	10.6	17
Eutrophycation potential, PO_4 kg	49	77	100	158	64	200
Acidification potential, SO_2 kg	173	306	394	471	163	380
Pesticides used, kg/ha	7.7	7.7	8.8	7.1	3.5	3.0
Land use, ha	0.64	0.67	0.74	2.33	1.20	1.40

Source: *Williams et al*., 2006

Broiler chicken, egg and pork production have a smaller environmental footprint compared to other production sectors. CO_2 output is an important contributor to global warming (as declared by the majority of experts, although by far not all).

In *Table 2* the CO_2 production of fattening pigs as affected by weight and growth potential are tabulated (*Jentsch et al.,* 2009).

Table 2

CO_2 production of fattening pigs as affected by live weight and growth potential

Bodyweight (kg)	BW gain (g)	CO_2 production (kg/kg BWG)
40	500	134
	700	1.26
60	400	1.85
	600	1.58
	800	1.46
80	400	2.11
	600	1.82
	800	1.67
100	500	2.11
	700	1.87
120	500	2.26
	700	2.02

Source: *Jentsch et al.,* 2009

In pigs during the fattening period an increase in daily weight gain by 200 g, decreases CO_2 emission by 10–15% per kg gain.

Very similar tendencies were published as for pigs for fattening bulls in the weight classes 200, 300, 400 and 500 kg. The CO_2 output per kg bodyweight gain was reduced if daily gain improved 400 g in the various weight classes by 17.3, 9.4, 8.6 and 8.5% respectively (*Jentsch et al.,* 2009).

Of special interest and importance is a publication of *Capper et al.* (2009) comparing the complex environmental impact of dairy production of the USA characteristic for 1944 and 2007 (*Table 3, 4*). The objective of that study was to compare the environmental impact of modern (2007) US dairy production with historical production practices as exemplified by the US dairy system in 1944. “The summary of this paper clearly demonstrates the huge impact of both genetic and managemental improvements on overall efficiency and reducing environmental pressure in milk production.” A common perception is that pasture based, low-input dairy systems characteristic of the 1940s were more conducive to environmental stewardship than modern milk production systems. A deterministic model based on the metabolism and nutrient requirements of the dairy herd was used to estimate resource inputs and waste outputs per billion kg of milk. Both the modern and historical production systems were modelled using characteristic management practices, herd population dynamics, and production data from US dairy farms. Modern dairy practices require considerably fewer resources than dairying in 1944 with 21% of animals, 23% of feedstuffs, 35% of the water, and only 10% of the land required to produce the same 1 billion kg of milk. Waste outputs were similarly reduced, with modern dairy systems producing 24% of the manure, 43% of CH_4, and 56% of N_2O per billion kg of milk compared with equivalent milk from historical dairying. The carbon footprint per billion kilograms of milk produced in 2007 was 37% of equivalent milk production in 1944. To fulfil the increasing requirements of the US population for dairy products, it is essential to adopt management practices and technologies that improve productive efficiency, allowing milk production to be increased while reducing resource use and mitigating environmental impact.”

Table 3

Characteristics of the 1944 and 2007 dairy production systems

Variable	1944	2007
Breed	54% Jersey/Guernsey/Ayrshire (small) 46% Holstein/Brown Swiss (large)	90% Holstein
Milk yield per cow, kg/yr	2.074	9.193
Milk fat content, %	4.20 (small breed) 3.60 (large breed)	3.69
Milk protein content, %	3.50 (small breed) 3.20 (large breed)	3.05
Heifer: cow ratio	0.89	0.83
Heifer growth rate, kg/d	0.42 (small breed) 0.59 (large breed)	0.68
Age at first calving, mo	27.0	25.5
Breeding method	100% natural service	70% AI, 30% natural service
Bull: cow ratio	1:25	0:83
Principal forage sources	Pasture, hay	Corn silage, alfalfa silage
Diet type	Forage + concentrate	Total mixed rations

Source: *Capper et al.*, 2009

Table 4

Comparison of resource inputs, waste output, and environmental impact of dairy production systems in 1944 and 2007

Variable	1944	2007
Milk produced, billion kg	53.1	84.2
	Resources/waste per billion kg milk produced	
Animals, n		
Lactating cows, × 10^3	414.8	93.6
Dry cows, × 10^3	67.4	15.2
Heifers, × 10^3	429.2	90.3
Mature bulls, × 10^3	19.29	1.31
Adolescent bulls, × 10^3	17.17	1.08
Total population, × 10^3	948	202
Nutrition resources		
Maintenance energy requirement[1], MJ × 10^9	16.66	3.87
Maintenance protein requirement,1 kg × 10^6	165.4	48.4
Feedstuffs, kg of fresh weight × 10^9	8.26	1.88
Land, ha × 10^3	1.705	162
Water, L × 10^9	10.76	3.79
Waste output		
Nitrogen excretion, kg × 10^6	17.47	7.91
Phosphorus excretion, kg × 10^6	11.21	3.31
Manure, fresh weight, kg × 10^9	7.86	1.91
Gas emission		
Methane[2], kg × 10^6	61.8	26.8
Nitrous oxide[3], kg × 10^3	412	230
Carbon footprint[4], kg of CO_2 × 10^9	3.66	1.35

Source: *Capper et al.,* 2009

[1]Refers to nutrient required for maintenance (all animals), pregnancy (dry cows), and growth (heifers and adolescent bulls); [2]Includes CH_4 emissions from enteric fermentation and manure; [3]Includes N_2O emissions from manure (both years) and from inorganic fertilizer application (2007 only); [4]Includes CO_2 emissions from animals, plus CO_2 equivalents from CH_4 and N_2O.

Based on *Capper et al.* (2009) data if the 1944 type typical milk production system would be applied at present, 143 million ha of land would be needed to supply the US population with 84 billion kg of milk. This would require 1/3 of the USA total agricultural area. The present system needs only 13.6 million ha-s (*Horn,* 2009).

To supply mankind with adequate animal products both quantitatively and qualitatively it is indispensable to utilize genetically further improved populations and complex managemental systems. This will be more important than ever before.

CONCLUSIONS

The manifold new challenges facing animal agriculture forces us to revaluate production efficiency in a more and more complex manner. The pressure to utilize all natural (and also human) resources more efficiently (water, feeds available, energy, land etc.) to meet growing demands both quantitatively and qualitatively inclusive food safety (all three are closely interrelated) we must be aware of the fact that in most cases to utilize highly productive genetic stocks, and matching production environment is inevitable. Efficient complex systems of production tend to have a reduced environmental footprint per unit animal product produced in all main species (poultry, pigs, cattle etc).

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