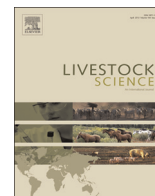




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# Production and environmental impact of dairy cattle production in Denmark 1900–2010

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## ABSTRACT

Cattle production during the last century has changed dramatically in Western Europe, including Denmark, with a steady increase in production per animal and in herd and farm size. The effect of these changes on total production, herd efficiency, surplus of nitrogen (N) at herd and farm level and emission of greenhouse gases (GHG) per kg product has been evaluated for the Danish dairy cattle sector based on historic information. Typical farms representing the average situation for Danish dairy cattle farms and land required for feed supply was modeled for the situation in: (A) 1920 – representing a local-based production, (B) 1950 – representing a period with emerging mechanization and introduction of new technologies and a more global market, (C) 1980 – representing a period with heavy use of external resources like fertilizer and feed protein and (D) 2010 – today with focus on balancing production and risk of environmental damage. In A, B and C, other livestock such as pigs and hens also played a role, while the dairy farm in 2010 only had cattle. In 1920 and 1950 the farm was based on 7–8 dairy cows producing typically 1800–3400 kg energy-corrected milk (ECM) per cow annually and fed primarily on pasture and hay, only to a limited extent supplemented with imported protein. In 1980 the herd size had increased to 20 dairy cows producing 5000 kg ECM each, and feeding was with silage instead of hay, but still included grazing and there was a larger proportion of imported feed. In 2010 the herd had increased to 134 dairy cows producing 9000 kg ECM per cow and fed indoors all year. During this period net energy used for milk and meat in % of total intake and land use per 1000 kg of milk has steadily decreased as a consequence of higher milk yield per cow and higher yields of forage per ha. In opposition, the utilization of N in the herd, while increasing from 1920 to 1950 and to 2010 showed a drop in the 1980 system, where also the environmental N surplus per ha farmland was highest (40; 65; 226; 148 kg N per ha farmland in the respective periods). The lower N efficiency in 1980 also resulted in an increased GHG emission per kg milk than in the preceding and following periods (2.23; 1.38; 1.94; 1.20 kg CO<sub>2</sub>-eq. per kg ECM in the respective periods). It is concluded that the biological and technical development has made it possible to reduce the environmental load of dairy production significantly, but that this requires a strong focus on nitrogen management at the farm level and production efficiency in the herd.

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## 1. Introduction

Agricultural production reflects the increase in the global population and changes in consumer behavior. This has led to a relatively larger increase in the livestock sector compared to the total food production and this development is expected to continue, leading to a substantial increase in global farmland surpluses of nitrogen and phosphorus (Bouwman et al., 2013). Ruminants are less efficient than mono-gastric animals in converting

feed energy and protein to food energy and protein. This leads to a higher waste production and risk of environmental pollution, including methane emission, and a higher land use.

Several papers have addressed this in a static time perspective based on the present situation, such as Lesschen et al. (2011) for European livestock, Gerber et al. (2011) for global dairy production and Nguyen et al. (2010) in a comparison of different beef systems in the EU, while only a few have looked at the development in a historical perspective. Hristov (2012) estimated that the emission of methane from past populations of wild ruminants would have been almost identical to the present emission of methane from wild animals and farmed animals in the US, while Capper et al. (2009) compared the US dairy production of 1944 with 2007 and

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estimated a reduction in the emission of greenhouse gases (GHG) of 37%, while in the same period milk production rose 59%. Capper (2011) found that US beef in 2007 produced 18% less manure than in 1977 and had reduced the emission of GHG per kg product by 16%. National evaluations of the environmental impact of agriculture in Denmark have estimated that since 1990 methane emissions have been reduced by 3%, while N<sub>2</sub>O emissions have been reduced by 32% (Nielsen et al., 2011). Vinther and Olsen (2013) estimated an average reduction in N surplus of 70 kg N per ha since 1990 for agricultural land in Denmark.

These changes reflect a combination of structural changes and political regulations of the sector as well as higher biological efficiency in the individual animal together with implementation of new technology and improved farm management. Evaluating the effect of these elements in a historical perspective can give insight into how efficiency may be improved and environmental impact from livestock reduced in the future.

The objective of this paper was to document how cattle production has changed in the last century with a steadily rising production per animal and increasing herd and farm size, and to quantify the effect of these changes on total production, herd efficiency, N surplus at herd and farm level and emission of greenhouse gases for the Danish dairy cattle sector based on available data from historical information.

## 2. Danish cattle production 1900–2010

The baseline data presented in this section, if no other references are given, are from national books of statistics (Danmarks Statistik, 1968, 1969) including data from 1900 until 1965, and thereafter updated annually, showing data for the year and for the last 10 years (Danmarks, 1971, 1981, 1991, 2001, and 2011).

The amount of milk delivered to the dairy industry increased from around 1700 Mkg at the start of the century until the 1930's, and has since then been around 5000 Mkg (Fig. 1). Production of beef meat increased until 1970, when the annual production was almost 300 Mkg, followed by a 50% reduction in the period 1970–2010 when beef production again reached the same level as in 1930. From Fig. 1 it can be seen that the number of dairy cows behind this production has been reduced from a maximum of 1.7 million heads in 1930 to less than a third, 568,000 heads, in 2010. Around 20% of the beef production in 2010 was from beef cattle, with 102,000 heads of beef cows producing 24 Mkg beef annually.

Farming structure has also changed over the last century. In 1950 there were dairy cattle on 89% of the farms in Denmark, with farms having an average of eight cows. In 1980 specialization had started and the proportion of farms with dairy cattle was reduced to 35%. This development continued, and in 2010 only 10% of Danish farms had dairy cattle, now with an average of 134 dairy

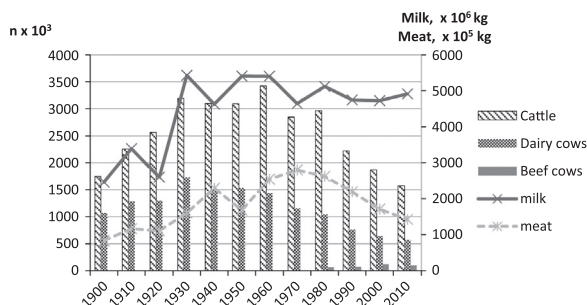


Fig. 1. Development since year 1900 in number of cattle (and dairy and beef cows) and the annual total production of milk and meat from cattle in Denmark.

cows per dairy farm. A similar trend for US dairy farming has been reported by Blayney (2002) for the period 1945–2000 and by March et al. (2014) for the British dairy industry since 1980.

The proportion of the different types of cattle (cows, heifers and bulls) within the dairy sector also changed during the century. In 1920 more than 60% of all dairy cattle were cows, and until 1950 more than half were dairy cows. This was due to the low profitability of beef production (Hansen and Livoni, 1959), which caused that more than one third of newborn calves to be either killed or slaughtered at a young age. This, together with a low reproduction rate and high mortality, resulted in a beef production of only 80 kg per cow and young stock (dairy production unit, DPU) in 1920 rising to 110 kg in 1950. In the following years there was a significant positive change in the economic conditions for beef farming, which together with improved reproduction increased the number of heads for slaughter and also the average weight at slaughter, leading to a maximum production in 1970–80 of 240 kg beef per DPU.

Productivity per animal has changed dramatically since 1900. Annual milk yield per cow, estimated as the amount delivered to the dairy, almost doubled in the first 70 years from 1900 to 1970, and more than doubled again in the last 40 year from 4000 kg in 1970 to almost 9000 kg in 2010 (Fig. 2). Fat concentration in the milk delivered to the dairy has increased steadily from 3.40% in 1900 to 4.43% in 1990, followed by a slight decrease to 4.30% fat in 2010. Regular data on protein concentration are only available since 1990, when the protein content was 3.38 – the same as today.

The development in milk and beef production has been influenced by a change in their genetic makeup, both between different types of breed and in genetic selection within breed. In the first part of the period Red Danish Cattle (RDM) (Andersen et al., 2003) was the dominating breed, representing more than 70% of the dairy cows, followed by 15–20% of the Danish Black and White (SDM) breed, and an increasing proportion of Jersey cows based on imported cows from the Island of Jersey at the start of the century (Johansen et al., 1963). The proportions of the breeds have changed over time due to large changes in the geographic location of the dairy cattle within Denmark in combination with different genetic developments for the different breeds, partly due to different opportunities for import of superior genes. The SDM cattle were mixed with the large global population of Holstein, increasing the popularity of this breed, so that in 1980 54% of the cows were SDM, only 22% RDM and 16% Jersey. In 2010, 72% of the dairy cattle were SDM (but had now changed the name to Danish Holstein due to the strong gene import), 13% were Jersey and only 7% were RDM (RYK, 2014), with an annual milk production of, respectively, 9518, 8492 and 8999 kg ECM (3.14 MJ/kg) per cow based on data from milk recordings. Østergaard and Neimann-Sørensen, 1989

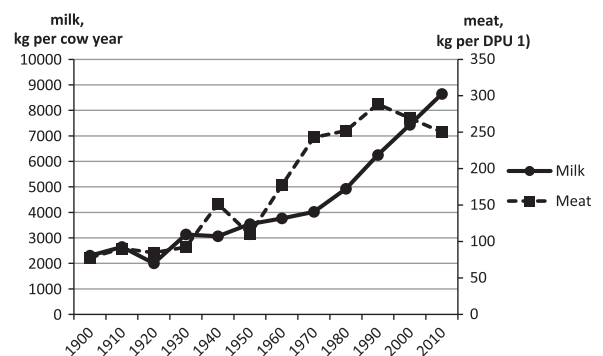


Fig. 2. Average production of milk and meat from dairy cattle since 1900 in Denmark, kg per DPU (1) DPU: One dairy cow including her offspring).

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