Multidimensional empirical based assessment of different pig production systems; the case of Denmark

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Abstract

The objective of this analysis is to evaluate performance of different existing production systems within pig production using Denmark as study case. Our approach is to evaluate, based on farm level data representative for the Danish pig industry, the impacts of pig production on five sustainability-related dimensions concerning environmental and climate impacts, animal welfare, antibiotics use and production cost. Our contribution is a coherent documentation and evaluation of the impact on five dimensions for existing production systems. The overall finding is that there are inherent trade-offs between the evaluated dimensions of pig production but also that trade-offs can be affected. The strength of the study is that results are based on a comprehensive dataset from Denmark enabling us to quantify the trade-offs.

Keywords: pig production, trade-offs, sustainability, Denmark, sustainability

Introduction

The climate impact of agricultural production is highly debated but also other impacts of agricultural production as well as attributes of food products give rise to controversy. These multiple goals of production and product attributes are often bundled under the heading "sustainability". The sustainability concept has been discussed since the take-off in the Brundtland report from 1987 (World Commission on Environment and Development, 1987) and the operationalization of the sustainability concept has been debated on multiple world conferences but none-the-less used with a more or less broad meaning (Gamborg and Sandøe 2005). Since 2015 the operationalization of sustainability has been formulated in UN's 17 sustainable development goals (SDG's).

The SDG's are not mutually independent which is also recognized in Nilsson et al., (2016) where some of the interactions between goals are mapped as synergies or conflicts to achieving other goals. Especially conflicts between SDG no. 2, zero hunger and hence food production and other

development goals are emphasized in Nilsson et al. (2016) which elucidates that food production is at odds with several other development goals.

Well aware that the sustainability concept is not well defined Li & Kallas (2021) argue that sustainable agricultural production should encompass several environmental, social and economic aspects, which also includes e.g. food quality and safety. Our choice of dimensions are based on an assessment of major externalities associated with pig production. Our assessment is supplemented with expert interviews within each dimension and in sustainability in general.

The distinct production systems existing in Denmark are basically composed of a standard production system and a set of certified production systems. The analysed systems beyond standard are 'animal welfare' production system based on indoor production system, 'raised without antibiotics', 'free range' and 'organic production'. The animal welfare meat production and the organic production are certified by the government, whereas raised without antibiotics (Danish Crown, 2020) and free range production is certified by industry.

These distinct production systems give rise to an array of specialty products. Raised without antibiotics is a concept evolving in the US (Singer et al., 2019) whereas the market driven welfare products are evolving in Europe with 'Beter Leven' in The Netherlands and 'Tierwohl' in Germany (Christensen et al., 2020). Free range and organic production systems have been around for decades and all together they represent a spectrum of specialty products in the Danish production which have European and American resonance.

Relevant data from each of these systems are used to assess the climate and environment impact of the production. On top of this, multiple environmental technologies can be applied to reduce the impacts of pork production. Also, these systems have different impacts on animal welfare, productivity and antibiotics use.

Our approach is to quantify, based on representative empirical studies, dimensions concerning environmental and climate impacts and in addition also animal welfare, antibiotics use and production cost. Our contribution is a coherent documentation and quantification of the impact on five dimensions with respect to existing production systems. The trade-offs between dimensions reflected here can be interpreted as the historical judicial and sectorial preferences in combination with choices made in the competitive markets. A major focus has, based on the trajectory of pork products, historically been on productivity improvements within the given judicial frames defining minimum impacts on animal welfare, antibiotics use, and the environment. However, in recent years there has been a production and market differentiation taking into account the other dimensions besides productivity.

The objective of this analysis is to quantify performance of different existing production systems within pig production by use of Denmark as study case.

Knowledge and quantification of the impacts of existing pig production systems can help guide future investments in pig production as well as guide the marketing strategy for pork products in the pork value chain. Future research and development can potentially help mitigate negative impacts in one dimension while improving performance in other dimensions.

Data / production systems

Production systems

Standard production system in Denmark is aligned with European legislation with small improvements concerning animal welfare but with country specific environmental regulation on nitrate leaching and ammonium emissions. We have chosen to describe and measure the standard production system as a system without environmental technologies even though this is not representative of the average non-specialty production system in Denmark.

The animal welfare production system is based on an indoor production system where the sows are loose-housed all times also around farrowing. The weaners and finisher pigs have at least 30 percent more space than standard production system. Tail docking is prohibited and more straw is used in this production system. This is a government certified production scheme.

The raised without antibiotics production system is based on standard production system but the system is essentially a management technology where the farmers only use antibiotics therapeutically and if a pig is treated the ear tag is removed. Hence, only pigs with ear-tags are approved within the system. This is an industry certified scheme.

The free range production system is a scheme with outdoor farrowing huts with space requirements for the hut and for free range area, a minimum weaning age of 30 days and 35 days on average. Weaners and finishers are allowed inside with outside access with higher space requirements than standard pigs. All pigs need to have access to roughage. Requirements in organic pig farming is minimum the same as the free range scheme but with higher space requirements and weaning age of minimum 40 days and 49 days on average. Further 95% of feed must be organic and locally grown. To meet these rules, the feed for the organic production system is based on Danish produced grain, field beans and rapeseed cake and conventional soybean meal. Roughage is either grass-clover or barley whole crop silage.

Environmental technologies

On top of the standard production system, the effect of a range of environmental and climate mitigation technologies are evaluated. The technologies are biogas, acidification of slurry, cooling of slurry and frequent sluicing and a range of combinations thereof. The biogas technology is used for about 15 percent of the finisher pigs in Denmark. The share of herds using the acidification technology is unfortunately not known. Cooling of slurry is a widely used technology to reduce ammonium emission from pig farms. The net cost of this technology is rather low because the energy can be used elsewhere on the farm; about 20 percent of all farms are using slurry cooling. Finally, the frequent sluicing is a low tech technology where the farmers are sluicing slurry frequently. More than 20 percent of the farms have employed an environmental technology and these are primarily employed by standard production system, hence the environmental and climate impact of the standard without (w/o) technology is higher than the average ‘standard’ farm in Denmark.

Production data

The distinct production systems analysed in the paper are basically composed of a standard production system and a set of certified production systems, which are representative for the trends in pig production in western countries. The indoor production systems are standard, animal welfare, and raised without antibiotics. The free range and organic production systems are based outside.

All pigs are slaughtered at 111.5 kg. The feed rations are identical for all conventional types and are based on barley, rape-, sunflower- and soybean meal adjusted in proportions respectively for sows, weaners and finishers to meet the Danish standards for energy and protein (Børsting & Hellwing,

2021). In organic pig farming, 95% of the feed must be organic and locally grown and all pigs need to have access to roughage. The sows housed outside will in addition have an intake of pasture during the summer. To meet these rules, the feed for the organic production system was based on Danish produced grain, field beans and rapeseed cake and conventional soybean meal. Roughage was either grass-clover or barley whole crop silage.

Methods

Climate and Environment

The environmental and climate impact are assessed by Life Cycle Assessment (LCA) based on the principles and model documented in Dorca-Preda et al. (2021).

The functional unit used in the analysis is the amount of meat produced at farm gate measured in kilo live weight (LW).

The impacts are measured within four environmental categories, global warming potential, eutrophication, acidification potential, and land occupation over one year.

The model by Dorca-Preda et al. (2021) is developed to handle pig farming systems based on indoor housing. The impact of the two types with partly outdoor housing was estimated by taking into account the manure emission factors for organic and free range type from Kai & Adamsen (2017). Impact from feed production was updated with respect to organic feed but otherwise originating from Mogensen et al. (2018).

Animal Welfare

Quantification of the animal welfare for the production systems builds on the methodology presented in Sandøe et al. (2020) in which a panel of international academic experts have rated the animal welfare associated with varying requirements for the different production systems. The experts have been asked 19 questions about how a given aspect of a production system, for example space per animal or access to various forms of environmental enrichment, affects the animal welfare of a pig. The answer was a score in the range of 1 through 10. This was followed by a question about the importance of each aspect from a welfare perspective – also in the range 1 through 10.

The five production systems analysed in this study have all been evaluated by the animal welfare tool. Use of the tool (Sandøe et al., 2020) revealed that the ranking of different production systems are robust to variation in experts' assessments.

Antibiotics use

The use of antibiotics is measured in average daily doses (ADD) which is defined as the amount of antibiotics 100 pigs on average is prescribed per day on average over the last 9-month period. The antibiotics use is known per age group because the prescriptions are attributed to a specified age group and the number of pigs within the age group is known.

Every production system includes three age groups with different ADD's implying that the antibiotics consumption should be weighted together to an overall index for the production system. The weighting of the antibiotics use for the different age groups are done on the basis of the aggregated weight of the animals within that age group.

Production costs

Cost of producing a pig from birth to slaughter vary and depends on among other things on the production system. The estimate of production costs for the standard production system originates from the calculation of the investment and production costs in the sow weaner operation as well as in the finisher production is the basis for a fair price of a weaner pig traded among Danish farmers. (Udesen, 2020).

Raised without antibiotics have lower costs for antibiotics but have higher labour costs and costs for vaccines. The increased labour costs are induced by higher management level, handling of ear tags and higher hygiene level. Free-range production system differs from the standard production system by having sows outdoor and that weaner and finisher pigs have outdoor access.

Finally, the costs of producing organic pigs are referenced from a negotiated price between sellers and buyers of organic pigs. On top of the requirements for free-range pigs, the organic pigs have even more space and the feed is produced organically.

Results

The results are kept qualitative because the analysis is being published in a journal article and hence the results cannot be presented here first. The environmental and climate impacts are even across the types with pigs raised indoor, while the free-range and organic production systems have higher impact than all the other production systems. The higher environmental impact for organic production is due to lower feed conversion rates, higher protein concentration and due to the lower organic crop yield. Organic production does also have a higher land use than indoor production systems.

The environmental and climate impact from standard production system can be mitigated by use of environmental technologies.

The results on the use of antibiotics make use of a weighting norm applied to weigh the antibiotics use of different age groups is animal weight within a year. The lowest antibiotics use is the production system “raised without antibiotics’. The organic production system has almost as low an antibiotics use as “raised without antibiotics”. The other production systems have higher antibiotics use.

Costs of adding environmental technologies are marginal compared to the cost differences across the production systems as the different technologies incur cost increases ranging from €0.5 per pig to €2.5 per pig. Costs of production are substantially higher for organic production and also higher for free range production compared to all indoor production systems.

Discussion and conclusion

Historically, a major focus has been on productivity improvements but even with this focus, some market-based initiatives have evolved with focus on environmental impact, animal welfare and antibiotics use. During the last decades, an increased focus on the impact of production on the environment and recently also climate impact have spurred these dimensions to be included in the assessment.

Interpretation of our findings

The main findings in this analysis is the complex trade-offs between different attributes of pork when produced in accordance with existing certified production schemes. With respect to the impact on climate, the current production systems analysed in this paper are not that different. This

is to some extent due to the standardization of the feed ration. If feed productions were varied, this could potentially give some effect, but this is expected to be independent of the production systems.

With respect to the impact on environment, there are quite large differences between highest and lowest impact with the organic production having highest impact. This could even be widened by use of environmental technologies in indoor production systems. The use of environmental technologies in Danish pig production is also found in Pexas et al. (2020) where they found a reduced impact on environment. In the dimensions animal welfare and antibiotics use, substantial differences between the production systems are present. The animal welfare index of the standard production system is only half of the organic type. Also, antibiotics use varies a lot with a double up in usage in the standard production compared to raised without antibiotics.

Not even if the consumer has unlimited willingness to pay, the consumer cannot have the high animal welfare, low antibiotics use, and low environmental and climate impact relative to the best practice. Organic production could be your choice, with high animal welfare and low antibiotics use but it has substantially higher environmental impact and slightly higher climate impact.

The overall finding is that there are inherent trade-offs between the evaluated dimensions of pig production. This is earlier found in case farms, but this study confirms the trade-offs based on a comprehensive dataset from Denmark.

Comparison and discussion in light of what others have found

In our analysis, we chose to assess the impact of pig production based on state-of-the-art measures but also with a pragmatic scope where the data at hand guided our ambitions in which measures to include. Our findings are aligned with findings in e.g. Zira et al. (2021) and Bonneau et al. (2014) where they also find trade-offs between animal welfare and environmental impact and production costs.

Scherer et al. (2018) incorporate the animal welfare dimension directly into the LCA but include e.g. only one measure for the quality of life which for pigs is the surface area available for each animal which obviously is not affected by e.g. use of anaesthetics under castration and e.g. only indirectly affected by the docking of tails. We acknowledge the importance of the animal welfare dimension in assessing pig production but we chose to have a comprehensive measure of animal welfare incorporating a wide array of welfare enriching attributes.

Strengths and limitations of our study

In the assessment of the Danish pork sector, we used the same feed for the whole conventional pork sector knowing that feedstuff is the major contributor to climate impacts of pork production. This choice is based on current practice when producing pigs in Denmark – simply because the producers do not have an incentive to choose other feedstuffs. If producers were given incentive to produce with lower climate impact some reductions could be made rather fast (Reckmann et al. 2016). This would though be independent of the production system analysed in this paper.

Our study did not include the global land use change because we did not have detailed information about the feed stuff used for every production system and because we chose to focus our analysis on the effect of production systems as well as manure handling practices.

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