Available online at www.centmapress.org

Proceedings in
System Dynamics and Innovation in Food Networks 2016

INTERNATIONAL JOURNAL ON FOOD SYSTEM DYNAMICS

Towards a Sustainable Meat Production with Precision Livestock Farming

Tom Van Hertem, Simon Lague, Luc Rooijakkers and Erik Vranken

Fancom Research, Fancom BV, Wilhelminastraat 17, 5981 XW Panningen, The Netherlands

tvhertem@fancom.com

ABSTRACT

In future years, modern farmers will be under greater pressure to care for a large number of animals in order to remain economically viable. There is a growing global awareness of welfare conditions in animal production and a tendency towards more intensive production, resulting in a need for better genetics and a more precise way to monitor them. The challenge and the success of intensive farming will lie in how precisely we can steer the animals towards their genetic potential. Sensors have the potential to replace the eyes, ears and nose of the farmer by continuously assessing different key indicators throughout the production process, 24 hours a day and 7 days a week. The continuous automated monitoring of varying needs of individual living farm animals at every moment and anywhere is called Precision Livestock Farming (PLF). The aim of this paper is to describe how PLF-systems are used within the EU-PLF project to work towards an automated assessment of sustainability on farm level, by continuous monitoring of animal behaviour. The roadmap towards a sustainable meat production, viewed from a technologist's point of view, is described hereafter in four steps. This phase comprises an implementation of PLF tools, where the basic inputs are measured and monitored in function of time. In a next step, a more complete control of the production process is pursued. In this step, the animal is used as a sensor to gather evidence on the animals' bio response to its environment and management by the farmer. The final step towards the management of the meat production is through the monitoring of emissions and resource efficiency. PLF-technology and continuous monitoring of animal bio responses will improve the understanding of the production process. This will allow the farmer to manage his process by exception. Production data collection and sharing will enhance the transparency throughout the production chain and help the consumer make educated decisions.

Introduction

The world population is expected to grow to 9.15 billion by 2050 according to the latest projections of the United Nations Population. The current population of 7 billion inhabitants, implies an increase of over 34%. In lower income countries this growth is likely to have higher economic implications and subsequently a higher impact on the worldwide demand for animal products. Strikingly, the number of livestock farmers is decreasing as the demand for livestock increases. This leads to larger farms and more intensive production.

In future years, modern farmers will be under greater pressure to care for a large number of animals in order to remain economically viable. Whilst society believes animals are entitled to receive individual attention, due to scale, farmers will have less time to extensively observe each individual animal. It is therefore practically impossible for most European farmers to meet society's belief that they have a strong relationship with their animals. As a result of this contradiction there are social and economic consequences for all stakeholders involved, specifically the animals and farmers. Besides this, there is an increasing awareness and concern about animal welfare and health. Today's consumers are more convinced that animals kept for food production should be raised, treated and slaughtered in a more humane way an should have a life worth living (Wathes *et al.*, 2007). While Europe has invested in developing standardized methodologies for assessing and scoring animal welfare at farm level (Blokhuis *et al.*, 2010) there is still a long way to go to actually improve animal welfare in intensive production systems. There is a growing global awareness of welfare conditions in animal production and a tendency towards more intensive production, resulting in a need for better genetics and a more precise way to monitor them. Intensification of livestock production, and agriculture in general, has also had an impact on the environment though its emissions of greenhouse gasses, ammonia and odour. Licentious application of manure on the crop fields has led to an eutrophication of the surface water in some regions in the world. Manure action plans have been started up to counter the effects of eutrophication. Odour emissions

DOI 2016: pfsd.2016.1638

are not wanted by the neighbouring community of the farms, and more and more protests occur when new plans for expansion are revealed. In this case, the consumer is applying the NIMBY-principle of 'Not In My Back Yard'.
Another key factor in the solution to feed the world will be the development of the genetics of the animals. The study of Zuidhof et al. (2014) showed that broiler growth increased by over 400% with a concurrent 50% reduction in feed conversion rate in the past 50 years. But they also mention the presence of unintended effects such as immune function due to the past selection programs. Therefore, the challenge and the success of intensive farming will lie in how precisely we can steer the animals towards their genetic potential.
Nowadays, a range of technologies are available that potentially can help farmers in real time monitoring of each individual animal. Information and computer technologies offer a huge potential for this. Sensors have the potential to replace the eyes, ears and nose of the farmer by continuously assessing different key indicators throughout the production process, 24 hours a day and 7 days a week. The continuous automated monitoring of varying needs of individual living farm animals at every moment and anywhere is called Precision Livestock Farming (PLF) (Berckmans, 2004). This results in "early warning systems" that improve the management of individual animals needs at any time (Kashiha *et al*., 2013). The use of modern technology offers several advantages like ensuring more attention and care to the individual animals but also automated welfare monitoring methods based on imaging and sounds. PLF has the potential to improve animal welfare, increase the technical results, and minimize the carbon footprint and thus improve the sustainability index of the farm. On top of that, the technology can monitor the animals 24 hours per day, and seven days a week, i.e. every minute of the animal's life whereas the farmer spends only a limited time to each individual bird.
Sound and image analysis are interesting non-invasive technologies to monitor a group of animals without interfering their natural behaviour. The significant potential to automate continuous measurements on farms using modern technologies has been demonstrated on six European Conferences on PLF and by peer-reviewed conference proceedings: ECPLF 2003 in Berlin, Germany (Werner and Jarfe, 2003), ECPLF 2005 in Uppsala, Sweden (Cox, 2005), ECPLF 2007 in Skiathos, Greece (Cox, 2007), ECPLF 2009 in Wageningen, the Netherlands (Lokhorst and Groot Koerkamp, 2009), ECPLF 2011 in Prague, Czech republic (Lokhorst and Berckmans, 2011), ECPLF 2013 in Leuven, Belgium (Berckmans and Vandermeulen, 2013) and ECPLF 2015 in Milano, Italy (Guarino and Berckmans, 2015). Despite the great potential of PLF, most farmers and other stakeholders (e.g. vets) do not currently have the skills to utilize these technologies effectively. It is time consuming to combine and analyse the data derived from different sensors in different formats and frequencies. An online visualisation tool to acquire, aggregate and visualise these sensor data is described in Koenders et al. (2015).

The aim of this paper is to describe how PLF-systems are used within the EU-PLF project to work towards an automated assessment of sustainability on farm level, by continuous monitoring of animal behaviour.

The use of PLF-technology towards sustainable farming

Modern farms are now equipped with new and existing PLF technologies. In each farm, dependent on the species, a number of selected key indicators, representing at least one of the domains welfare and health, environmental load and productivity are monitored by the implemented systems. The roadmap towards a sustainable meat production, viewed from a technologist's point of view, is described hereafter in four steps.

Step 1. Measuring input and output

This phase comprises an implementation of PLF tools, where the basic inputs are measured and monitored in function of time. The main inputs are feed and climate. Automation of the feed delivery will allow ad libitum feeding through an instant and automatic refilling of the feed bunker when feed is getting scarce in the house. Temperature based climate control is necessary for an optimal growth response of the animal to the delivered feed. Suboptimal temperatures will induce heat or cold stress on the animals, where energy will be spilled in maintaining a constant body temperature.

Step 2. Complete control

In a next step, a more complete control of the production process is pursued. Automatic weight measurements allow the steering of the growth during the production process. Feed input can be adjusted to the growth output of the animal when necessary. Influencing factors affecting this feed-growth relation are ambient indoor temperature, relative humidity and water intake of the animals. Continuous monitoring of these variables will help in fine-tuning the growth response of the animals. To steer the production efficiency towards a more efficient production of meat, key indicators have to be identified. A commonly used key indicator is the Feed Conversion Rate (FCR), which is the ratio between the amount of feed supplied to the

DOI 2016: pfsd.2016.1638

animal and the growth. A better, i.e. lower FCR implies that less feed is supplied for the same production of meat. A more extended key indicator is the European Production Efficiency Factor (EPEF), which includes the FCR, mortality and the length of the production cycle. A higher EPEF implies that the cycle had a better FCR, a lower mortality and a shorter rearing period.

Step 3. Welfare and Health Control

In this step, the animal is used as a sensor to gather evidence on the animals' bio response to its environment and management by the farmer. The welfare of an animal is related to its physical and the mental state. The Farm Animal Welfare Council (FAWC) defined in 1979 the five freedoms as a comprehensive framework to safeguard and improve animal welfare (http:/www.fawc.org.uk/). The definitions of these freedoms are:

1. Freedom from hunger and thirst;
2. Freedom from discomfort;
3. Freedom from pain, injury or disease;
4. Freedom to express normal behaviour;
5. Freedom from fear and distress.

Following this, the Welfare Quality consortium developed a Protocol (Blokhuis *et al*., 2010) to assess the welfare status of the animals during the production cycle. They have identified 4 principles with 12 criteria to objectively quantify the welfare level of the flock or herd. The assessments are usually done by a human observer, hence infrequently, expensive and time-consuming. At every farm several manual welfare assessments were performed (broilers: 3 times per flock, pigs: every month). Due to budget and time constraints, not every flock was assessed. The welfare assessment consisted of several measurements defined by the Welfare Quality protocol, such as coughing, sneezing, tail biting and body wounds for pigs, and foot pad lesions, lameness, litter quality and the avoidance distance test for broilers. The need for automated welfare and health assessments is growing. Sensor techniques such as cameras, microphones and electronic noses have the potential to replace the eyes, ears and nose of the farmer in the house. The FAWC states that stockmanship, plus training and supervision are necessary to achieve the required standards. PLF-technologies can assist the farmer in the supervision of his animals on a 24/7 basis.

Two PLF-technologies that are used in the EUPLF-project are the camera-based eYeNamic™ system (Fancom BV®, Panningen, the Netherlands) and the microphone based Sound Monitor (Soundtalks®, Leuven Belgium). At the majority of the farms, the existing climate and feed controls were Fancom® controls. At these farms additional software was installed to sample climate and feed data. This data is different for each farm. There is a big variety in climate and feed controls and sample options. For the availability of this data the authors depended on existing installations and configurations.

The eYeNamic™ camera system was used in both pig and poultry farms. Images were recorded from a top down perspective. The frame rate of the camera was 3 frames per second, and every minute a new image was saved to the hard disk. Animal shapes were automatically segmented from the background floor area. Further image analysis translated the acquired images into indices of distribution and activity (Kashiha *et al*., 2013). These indices are a measure of the animals' position and movement, and can help in monitoring and studying basic animal behaviour. The camera system was installed in all five broiler farms (four cameras per farm) and all ten pig farms (four cameras divided over four compartments). The eYeNamic activity levels show correlation with the level of foot pad lesions in the house (Pena Fernandez et al., 2015). The study of Colles et al. (2016) has shown the potential of animal activity monitoring in relation to Campylobacter infections in a poultry house, and the work of Dawkins et al. (2004) the relation between behaviour and welfare.

The Pig Cough Monitor™ (PCM) was developed by Soundtalks®, and validated as a tool for automated pig cough detection in a pig house by Guarino et al. (2008) and Hemeryck et al. (2015). The PCM was installed in four compartments on each of the ten pig farms. The sound data was stored every five minutes (for example the number of coughs within the last five minutes). A mathematical algorithm processed all sound files, and identified the number of coughs in each recorded sound fragment. Pig coughing is a clinical sign of pleuritic or pneumonia.

Step 4. Sustainability Management

The final step towards the management of the meat production is through the monitoring of sustainability. A key role in this is the monitoring of the emissions. Emission products such as ammonia, odour, greenhouse gasses and manure are now considered to be unwanted by-products of the production process, but most of them can serve as an input in other processes. By reducing the emissions throughout the production process,

DOI 2016: pfsd.2016.1638

resource usage can be optimized and the impact on the environment will be consequently reduced. Future meat production should evolve towards a system where resources are being reused and supplied according to the needs of the animal. With the implementation of air washers, litter burners and solar energy, … it is even possible to evolve towards a production cycle with a negative footprint.

EUPLF-project: commercial farm applications

Within the EU-PLF project, 10 pig farms and 5 poultry farms were equipped with new and existing PLF technologies. In each farm, dependent on the species, a number of selected key indicators, representing at least one of the domains welfare and health, environmental load and productivity are monitored by the implemented systems (Table 1). The data derived from the different sensors is processed, joined, and aggregated (mean, maximum, or minimum) to one value per day for each variable. Every night the daily data are calculated on the local farm pc. The results are automatically uploaded to an online data server. A logbook is nested into the visualisation tool for record keeping of events happened during the production. These records are stored on the online data server.

Table 1. Overview of the available sensory data in the EUPLF project in relation with the steps towards sustainability management.

Steps towards sustainability management	Sensory data in EUPLF project
Step 1. Measuring input and output	Indoor temperature, feed supply
Step 2. Complete control	+ outdoor temperature, relative humidity, air pressure, ventilation rate, heating time, water supply, animal weight, animal growth, management software
Step 3. Welfare and Health Control	+ animal activity, animal distribution in pen, pig coughing, animal resting time, mortality
Step 4. Sustainability Management	+ CO_2, dust

For data visualisation, web2py (www.web2py.com) was used. Web2py is a free, open-source web framework for agile development of secure database-driven web applications, implemented in Python (www.python.org) (van Rossum, 1995). Web2py is a full-stack framework, meaning that it contains all the components you need to build fully functional web applications. Web2py encourages the developer to separate data representation (the model), data presentation (the view) and the application workflow (the controller).
For the graphics Highcharts (www.highcharts.com) (Di Pierro, 2011) was used. Highcharts is a charting library written in pure JavaScript, offering an easy way of adding interactive charts to your web site or web application.
The visualisation tool is hosted at pythonanywhere (www.pythonanywhere.com). Pythonanywhere makes it easy to create and run python programs in the cloud. There is storage space and one can configure his own webserver. By making use of these tools it is possible to make a visualisation in little time, with minimum amount of code, and which can be used on different platforms (windows, mac, desktop, mobile, tablet).

Discussion

In this paper, we have presented four different stages of sustainable production. In the past, farming was very laborious, and the farmer was only interested in maximizing his “work output”:”time effort“-ratio. The automation of certain processes allowed him to significantly improve this ratio, for example an automatic feeding line reduced the workload of the farmer to feed the animals. The next step was to add some intelligence to the automatic systems, e.g. start feed delivery when feeding pans are empty, or start the ventilation when temperature is too high. This is equal to the first step in the sustainability process that we present here.
The next steps involve more intelligence in process automation, and a better understanding of the production process. Maximum sustainability is however obtained at the final stage, when the complete production process is controlled. The need of the individual animal will play a bigger role as we move higher up the ladder of sustainability. So although adding more automation and technology to the production process looks like industrial farming, in fact the individual animal will get more attention.

DOI 2016: pfsd.2016.1638

We in Fancom, a technology developer, develop PLF sensor techniques and automated controls for farmers so they maximize their profits. There is a wide range of tools in the market, but we see that in reality 90% of the farmers are still in the first stage of a very basic implementation with a feed and climate control. But we also know that there is the capability for all farmers to be at the fourth and final step towards sustainable meat production.

The main hesitation for most of the farmers to invest into PLF-technology is high investment cost and the unawareness on the return on investment. On the other hand, we also don't know what is the cost of not investing in PLF-technology. The value that PLF will bring, cannot not be quantified in hard numbers alone. However, some of the farmers in the EUPLF project that started using the PLF technology acknowledge the benefits of the technology. They state that it allows them to focus on the animals when near the animals, and on the management and operations when in the office. They stated that PLF changed their way of working due to a better organisation of their own time budget. A simple example of this is that with the pig cough monitor, the farmer could easily identify compartments at risk, and visit these compartments at the end of his inspection round to reduce the risk for transmission of the disease between compartments.

Precision Livestock Farming is a hot topic in the research community. New technologies and sensor techniques are coming more and more into the commercial market. PLF-technology for health, welfare and emission monitoring is not in large numbers commercially available at this moment. There are however many application in the research pipeline that will evolve into commercial products in the near future. Therefore, we are growing closer and closer towards the automatic monitoring of a sustainable meat production.

Consumer organisations are raising more and more protests against modern intensive farming. A change in the way of how we produce our meat seems to be inevitable. Some retail organisations and NGOs have developed their own brand or method for meat production. Those are usually focused on the welfare of the animal, or on the environmental footprint of the production cycle to substitute for production efficiency. Those types of farming are useful in the current world with various consumers, but they will not solve the problem on how to feed the world. Therefore, a more sustainable intensive farming is needed, and with the continuous monitoring of the animals with PLF technology, this can be achieved.

Conclusion

The global demand for meat is growing. We believe intensification is a viable option to answer this demand. However, a responsible production is needed. Production efficiency should not be the exclusive factor to manage the meat production process. Instead, the animal should be at the centre of the equation. With the help of PLF technology, we can gather as much information as possible during the production process. The use of automated and intelligent systems is key in this. PLF-technology and continuous monitoring of animal bio responses will improve the understanding of the production process. This will allow the farmer to manage his process by exception, i.e. only take action when the process deviates from the expected outcome instead of applying preventive measures such administering antibiotics at group level. Production data collection and sharing will enhance the transparency throughout the production chain and help the consumer make educated decisions. Therefore, we call way of farming iFarming: 'If Philosophy needs a name and **INTELLIGENT** farming allows 'us' to make **INTELLIGENT** decisions, why not call it iFarming'.

Acknowledgements

This project was funded by the collaborative project EU-PLF KBBE.2012.1.1-02-311825 under the 7th framework program.

References

Berckmans, D. 2004. Automatic on-line monitoring of animals by precision livestock farming. *International Society for Animal Hygiene* 2004

Berckmans, D. and Vandermeulen, J. 2013. Precision Livestock Farming '13, *Wageningen Academic Publishers*, First publication, 968 pages

Blokhuis, H.J., Veissier, I., Miele, M., Jones, B. 2010. The Welfare Quality® project and beyond: Safeguarding farm animal well-being. *Acta Agriculturae Scandinavica, Section A — Animal Science* Volume 60, Issue 3

Colles, F. M., Cain, R., Nickson, T., Smith, A. L., Roberts, S. J., Maiden, M. C. J., Lunn, D. and Dawkins, M. S. (2016). Monitoring chicken flock behaviour provides early warning of infection by human pathogen Campylobacter. *Proceedings of the Royal Society*, *283*(1), 6. http://doi.org/10.1098/rspb.2015.2323

DOI 2016: pfsd.2016.1638

Cox, S. 2005. Precision Livestock Farming '05, *Wageningen Academic Publishers*, First publication, 358 pages
Cox, S. 2007. Precision Livestock Farming '07, *Wageningen Academic Publishers*, First publication, 312 pages.
Dawkins, M.S. 2004. Using behaviour to assess animal welfare. *Animal Welfare*, 13, 3-7.
Di Pierro, M. 2011. Web2py for Scientific Applications. *Computing in Science & Engineering,* 13, 64
FAO. 2007. Corporate Document Repository, Global and regional food consumption patterns and trends, Agriculture and Consumer Protection report
Guarino, M., Jans, P., Costa, A., Aerts, J.M., Berckmans, D. 2008. Field test of algorithm for automatic cough detection in pig houses. *Computers and Electronics in Agriculture* Volume 62, Issue 1, Pages 22–28
Guarino, M. and Berckmans, D. 2015. Precision Livestock Farming '15, *Wageningen Academic Publishers*, First publication, 831 pages.
Koenders, E., Rooijakkers, L., Van Hertem, T., Vranken, E., Berckmans, D., Berckmans, D. (2015). Towards the development of a practical visualisation tool for farmers and other stakeholders. In Guarino, M. (Ed.), Berckmans, D. (Ed.), *Precision Livestock Farming '15*. European Conference on Precision Livestock Farming. Milano, Italy, 15-18 September 2015 (pp. 327-337).
Lokhorst, C. and Groot Koerkamp, P.W.G. 2009. Precision Livestock Farming '09, *Wageningen Academic Publishers*, First publication, 368 pages
Lokhorst, C. and Berckmans, D. 2011. Precision Livestock Farming '11, *Czech Centre for Science and Society*, First publication, 541 pages
Kashiha, M., Pluk, A., Bahr, C., Vranken, E., Berckmars, D. 2013. Development of an early warning system for a broiler house using computer vision. *Biosystems Engineering,* Volume 116, Issue 1, Pages 36–45.
Peña Fernández, A., Tullo, E., Exadaktylos, V., Vranken, E., Guarino, M., Berckmans, D. (2015). Broiler activity and distribution as behavior-based welfare indicators. In Guarino, M. (Ed.), Berckmans, D. (Ed.), *Precision Livestock Farming '15: Vol. 1*. European Conference on Precision Livestock Farming (EC-PLF). Milan, 15-18 September 2015 (pp.208-217).
van Rossum, G. 1995. Python tutorial, Technical Report CS-R9526, *National research institute for mathematics and computer science (CWI) Amsterdam*
Wathes, C., Kristensen, H., Aerts, J. M., and Berckmans, D. 2008. Is precision livestock farming an engineer's daydream or nightmare, an animal's friend or foe, and a farmer's panacea or pitfall? *Computers and Electronics in Agriculture*, 64(1), pp. 2–10
Werner, A. and Jarfe, A. 2003. Programme book of the joint conference of ECPA-ECPLF. *Wageningen Academic Publishers*, First publication, 846 pages.
Zuidhof, M.J., Schneider, B.L., Carney, V.L., Korver, D.R. and Robinson, F.E. 2014. Growth, efficiency, and yield of commercial broilers from 1957, 1978, and 2005. *Poultry Science*, 93(12): 2970-2982.

DOI 2016: pfsd.2016.1638