The Pig Cough Monitor in the EU-PLF project: results and multimodal data analysis in two case studies

M. Hemeryck[1, 2], D. Berckmans[1], E. Vranken[3], E. Tullo[4], I. Fontana[4], M. Guarino[4] and T. van Waterschoot[2]
[1]*SoundTalks, Kapeldreef 60, 3001 Leuven, Belgium*
[2]*KU Leuven, Department of Electrical Engineering (ESAT-ETC/STADIUS), Kasteelpark Arenberg 10, 3001 Leuven, Belgium*
[3]*KU Leuven, Department of Biosystems, Division M3-BIORES: Measure, Model & Manage Bioresponses, Kasteelpark Arenberg 30, 3001 Leuven, Belgium*
[4]*Department of Health, Animal Science and Food Safety (VESPA), University of Milan, Via Celoria 10, 20133 Milan, Italy*
martijn.hemeryck@soundtalks.com

Abstract

Precision Livestock Farming (PLF) combines the principles of process control technology with animal sciences. An example of PLF is the Pig Cough Monitor (PCM), which performs a continuous automated measurement of porcine respiratory health through sound analysis. This paper provides results and a thorough analysis of the data obtained in the course of the FP7 EU-PLF project. Earlier work has demonstrated the effectiveness of the PCM in a real-world farm setting. This paper reports on 2 new case studies, again using the cough index as a principal measure. Additionally, the heat map is introduced as a new visualisation approach of cough behaviour. The heat map shows the course of cough throughout the day. Additional sources of metadata such as the corresponding slaughterhouse data are also included. For both cases discussed in this paper, anomalies in the respiratory health are apparent from the cough index representations.

Keywords: precision livestock farming, acoustic monitoring, fattening pigs, EU-PLF, pig cough monitor, heat map

Introduction

In recent years, traditional livestock farming has come under stress by a growing global demand for meat and augmented ethical end environmental concerns towards meat production. In order to increase efficiency in livestock farming, Hanton and Leach introduced the idea of describing livestock farming as a process control technology (Hanton and Leach 1981). With the above issues in mind, Berckmans presented the idea of Precision Livestock Farming (PLF) (Berckmans 2006). The last years have seen the development of various instances of PLF-techniques (Daniella Jorge de Moura et al. 2008; Aydin et al. 2014). Methods specifically oriented towards acoustic monitoring of cough in pigs have also appeared and since undergone a long research trajectory (Moshou et al. 2001b; Moshou et al. 2001a; Van Hirtum 2002; Guarino et al. 2008; Exadaktylos et al. 2008; Vandermeulen et al. 2013). In 2011, SoundTalks NV and Fancom BV together released the Pig Cough Monitor (PCM) as a commercialisation of the earlier research on pig cough detection.

In this work, we hypothesise that a continuous measurement of cough behaviour has an added value in terms of speed as opposed to assessments at discrete time points. Furthermore, we consider our novel visualisation approach, a heat map representation, to give even more detailed insight into the cough dynamics over a fattening round.

Materials and methods

EU-PLF

The data presented in this paper was obtained in the Collaborative Project EU-PLF KBBE.2012.1.1-02-311825 under the Seventh Framework Programme. Within this project, 40 compartments of fattening pigs (four per farm) are monitored during a combined total of 60 fattening rounds. 10 pig farms were selected, located in France, Hungary, Italy, the Netherlands, the United Kingdom and Spain. The underlying objective of this large geographical spread was to cover a wide range of climatological conditions, management styles, housing layouts and materials, pig breeds etc. The data that is collected contains both qualitative and quantitative sources of information. The qualitative data consists of animal welfare assessments by trained experts or veterinarians as well as input from the involved farmers. Instances of quantitative data are the PCM-data. The aggregation of these inputs should provide a better understanding, both out of a scientific interest as well as to how PLF-technology can be employed to support the farmer in an economically viable way. The EU-PLF project ends in November 2016.

PCM-system

The sound acquisition system of the PCM consists of a condenser microphone (type Behringer C4) and a sound card (type ESI Maya 44). The microphones are phantom-powered and are connected using balanced audio, in order to allow the use of long cables with very limited susceptibility to noise. The sound data is recorded with a precision of 16 bits and a sampling frequency of 22 050 Hz. The sound card is mounted in an embedded board (x64 architecture), running a GNU/Linux operating system. The embedded board is fanless and installed in a sealed enclosure to protect the system from the harsh environment. The microphone itself is protected with a thin and flexible plastic cover in order to withstand the harsh conditions in the compartment whilst at the same time not interfering with the sound acquisition itself in the frequency range of interest. The embedded board is equipped with diagnostics software that regularly checks the system operation, including monitoring the sound recording quality, the system temperature and processing load. The system condition can be checked remotely via a wired or wireless internet connection. Several factors put high stress on the equipment and demand for a robust design as well as automatic diagnostic utilities built into the equipment, including unstable power supplies, high temperatures and humidity, acid compounds in the air, internet connection problems, accelerated corrosion due to ammonia concentrations, rats biting cables, etc. … An overview of practical difficulties associated with deploying PLF technologies on farm, and the solutions invented to overcome these, are listed in (Banhazi et al. 2014).

The microphone is typically mounted in the centre of the pig compartment, at a height of at least 2 m. Recordings are continuous, i.e. 24 h / d, 7 d / w. All raw sound recordings are stored on external hard drives, in order to allow further post-processing if

needed. The PCM runs software containing a cough detection algorithm to separate cough sounds from other sounds. Such an algorithm typically consists of the following steps. First, a procedure is carried out that isolates meaningful audio events for which distinguishing time-frequency features are derived. Secondly, there is a classification phase where cough sounds are separated from non-cough sounds based on those audio features. The algorithm is designed with the commercial setting in mind, i.e. the audio features that are used aim to be robust to all possible acoustic environments and practical farm conditions.

Case outline

Two case studies of the PCM are further discussed, each from a different farm involved in the EU-PLF project. The farms are referred to as farm A and farm B. The PCM-data is presented over the duration of a single fattening batch for both cases. The cases were selected based on logbook entries. Both of the selected cases are discussed in terms of the detected level of coughing and the corresponding case metadata.

The cough level is first displayed through a cough index graph. This graph shows the number of coughs per day throughout the fattening round, normalised for the number of animals. A novel method of visualising the cough index graph is the heat map. The heat map displays the intensity of cough both throughout the duration of the fattening round as well as throughout the day. It represents the cough index in these two dimensions by putting the day in the batch on the horizontal axis and the hour of the day on the vertical axis, indicating the intensity on a colour scale. It enables a more detailed analysis of the cough data.

The case metadata consists of animal assessments and logbook entries. The animal assessments are carried out by trained animal experts on regular, fixed time slots. They include the counting of cough events for a selected number of animals during a fixed time of 10 minutes. The logbook entries are notes on farm events by the involved farmers, veterinarians, caretakers or technicians. Case 1 describes a batch on farm A ranging from March 29th 2014 till June 24th 2014. The pig breed used on this farm is Topigs (Dutch F1) x Topigs (Tempo). The initial number of animals for this batch is 200. Case 2 describes a batch on farm B ranging from April 20th 2014 till August 25th 2014. The specific pig breed used for farm B is 25% Large White / 25% Landrace / 50% Piétrain. The initial number of animals for this batch is 192. For this case, the cough index data is presented and related to the corresponding slaughterhouse data.

Results and discussion

Case 1: batch farm A

Figure 1 and Figure 2 respectively show the normalised cough index graph and heat map. The beginning of the batch starts at 1.4 coughs per animal per day. After the first week, the cough index level increases to a maximum level of 4.5. The following and largest portion of the batch varies around a level of 2.5. Near the end of the batch, there is a large relatively increase to cough index 9.9. The heat map indicates that from June 6th to June 20th, the coughing is at an elevated level throughout the day.

Table 1 shows the results from the animal expert assessments for this batch. Note that this data does not reveal any particular onset of disease.

Table 1: Animal expert assessments case 1

Assessment	Date	# Animals	Start time	End time	# Coughs
1	2014-04-18	200	10:22	/	1
2	2014-05-23	199	11:38	11:48	3

Table 2 gives an overview of the information available from the slaughterhouse data. From this batch, 25 selected animals were analysed. The mean and standard deviation weight of the animals was respectively 76.6 kg and 4.2 kg. Out of the 25 animals, 12 animals tested positive for pneumonia and 3 for pleuritis. The animals were also classified on the SEUROP-scale (Council Regulation (EC) 1984), a subjective visual measure to grade carcasses in terms of lean meat content. Using this scale, 5 animals were graded as S, 18 as E and 2 as U.

Table 2: Summary of slaughterhouse data 2014-06-25 available for case 1

# Animals	Mean / std weight (kg)	# Pneumonia	# Pleuritis	# S	# E	# U
25	76.6 / 4.2	12	3	5	18	2

In summary, the cough index data reported a varying level of cough index with a large increase near the end of the batch. The animal assessment data did not reveal any particular onset of disease. However, the corresponding slaughterhouse data clearly showed the presence of disease for this batch, with 12 out of 25 animals positive for pneumonia. This indicates the clear added value of a continuous monitoring of the cough behaviour as opposed to the manual cough counting in a limited time span.

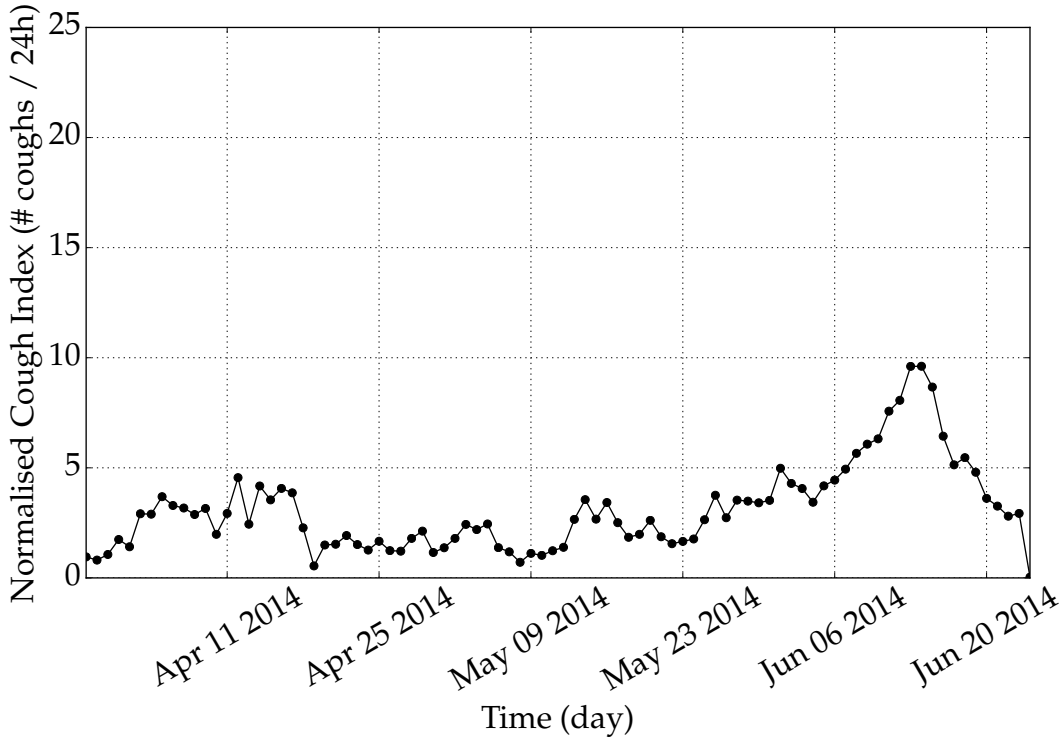


Figure 1: Normalised cough index graph case 1 showing relative peak around June 14th 2014

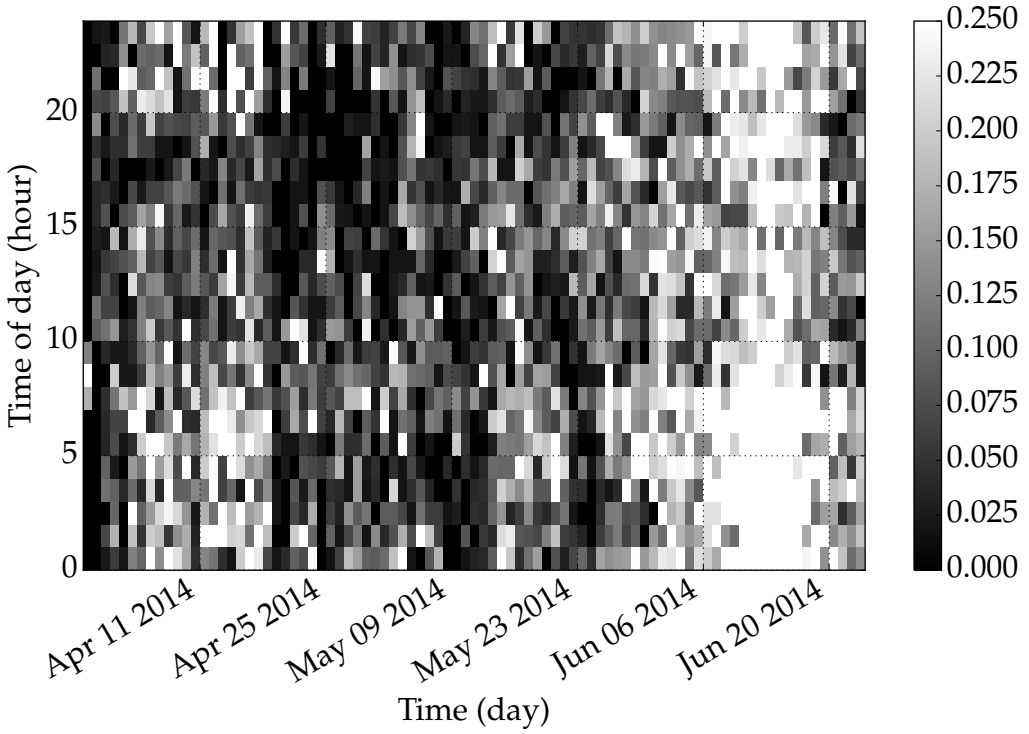


Figure 2: Cough index heat map case 1 showing elevated level of coughing throughout the day from June 6th to June 20th 2014

Case 2: batch farm B

Figure 3 shows the cough index graph and Figure 4 the corresponding heat map for this batch. The beginning of the batch shows a normalised cough index level of 10. On June 5th, the level increases from 17.7 to 36. On July 1st, another large increase from 20.9 to 44.8 is apparent. The heat map indicates that for both peaks the cough index is elevated throughout the complete day. Between May 30th and June 5th, recording data is missing.

Table 3 shows the assessments for this case. The assessments only describe discrete periods of time in the fattening round and thus cannot be related to the earlier mentioned peaks.

Table 3: Animal expert assessments case 1

Assessment	Date	# Animals	Start time	End time	# Coughs
1	2014-06-18	192	10:58	/	57
2	2014-07-21	189	10:44	/	32

An explanation for the peaks can be found in the logbook. The logbook indicates two issues for the beginning of June for farm B. The first peak can be explained through an issue with the air washer. As the air washer was blocked, the airflow through the unit was reduced. The climate control system requires certain airflow, but as the washer was blocked, only about 60% of the airflow was generated. The second peak can be explained by the presence of pneumonia, confirmed by the involved veterinarian.

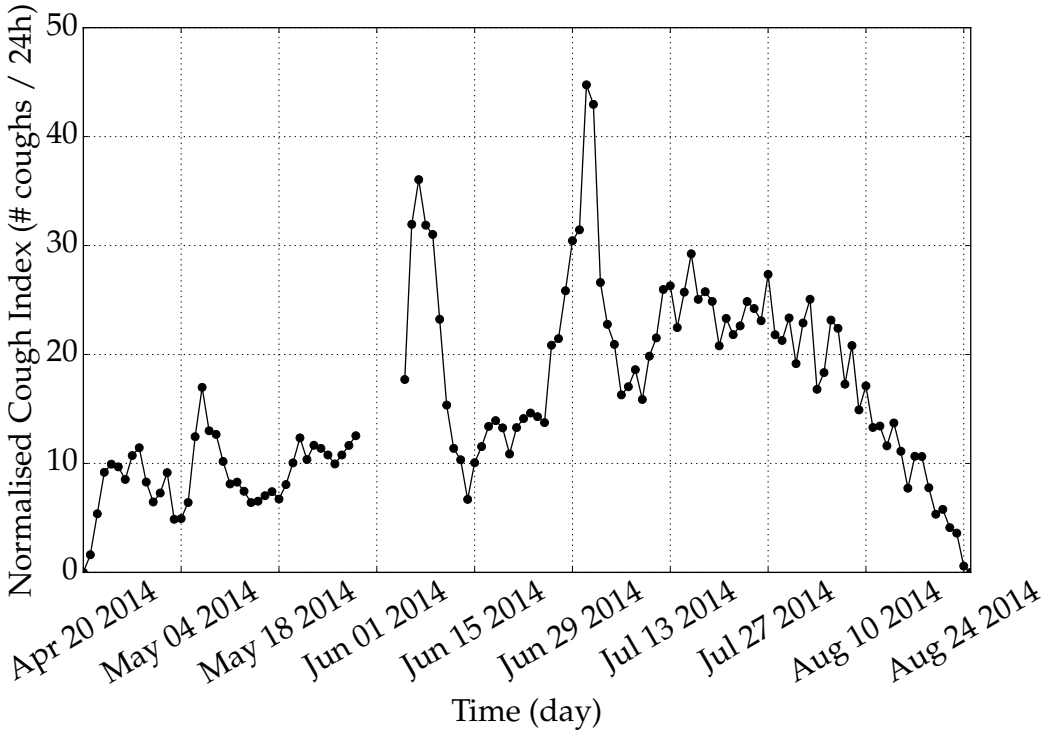


Figure 3: Normalised cough index graph case 2 showing 2 distinct peaks. The first peak is attributed to a malfunctioning air washer, the second peak to incidence of pneumonia.

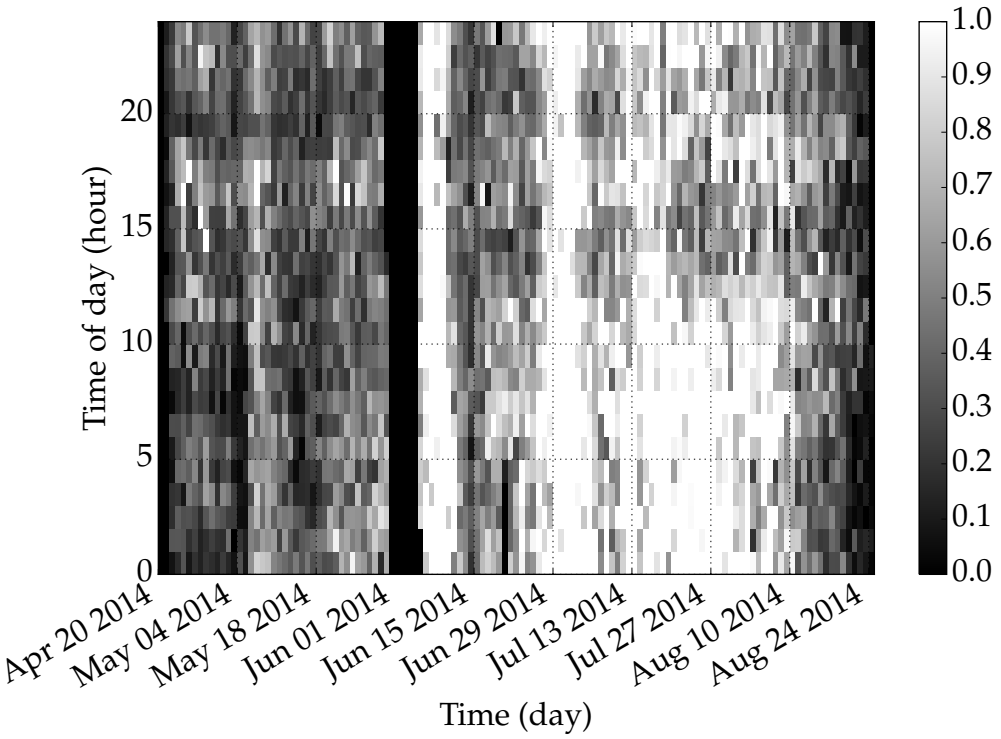


Figure 4: Normalised cough index heat map case 2 showing 2 distinct periods of elevated cough throughout the day. The first peak is attributed to a malfunctioning air washer, the second peak to the incidence of pneumonia.

Conclusions

Earlier work indicated the use of the PCM as real-world application of the principles of Precision Livestock Farming. In this paper, two more case studies of pig cough detection were discussed. Both fattening batches were measured on European farms that are part of the EU-PLF project. Again, the advantage of a continuous measurement of cough behaviour was demonstrated over the discrete cough counting. In addition, this research adds a novel visualisation approach, the heat map, to show the hourly variation of cough index throughout the day. Furthermore, the first case includes related slaughterhouse data in the analysis. Follow-up research should continue these analyses with focus on the further integration of the various sources of information.

Acknowledgements

The authors gratefully acknowledge the European Community for financial participation in Collaborative Project EU-PLF KBBE.2012.1.1-02-311825 under the Seventh Framework Programme. This work is supported by funding of the IWT Baekeland (Agentschap voor Innovatie door Wetenschap en Technologie — Agency for Innovation by Science and Technology in Flanders) (No. IWT 140245).

Disclaimer

The views expressed in this publication are the sole responsibility of the author(s) and do not necessarily reflect the views of the European Commission. Neither the European Commission nor any person acting on behalf of the Commission is responsible for potential uses of this information. The information in this document is provided with no guarantee or warranty that the information is fit for any particular purpose. The user thereof uses the information at his or her sole risk and liability.

References

Aydin, A., C. Bahr, S. Viazzi, V. Exadaktylos, J. Buyse, and D. Berckmans. 2014. "A Novel Method to Automatically Measure the Feed Intake of Broiler Chickens by Sound Technology." *Computers and Electronics in Agriculture* 101 (February): 17–23. doi:10.1016/j.compag.2013.11.012.

Banhazi, T., E. Vranken, D. Berckmans, L. Rooijakkers, and D. Berckmans. 2014. "Practical Problems Associated with Large Scale Deployment of PLF Technologies on Commercial Farms." In *Sessions of the EAAP Annual Meeting*. Copenhagen, Denmark: Wageningen Academic Publishers.

Berckmans, Daniel. 2006. "Automatic on-Line Monitoring of Animals by Precision Livestock Farming." In *Livestock Production and Society*, edited by R. Geers and F. Madec, 51–54. Wageningen Academic Publishers.

Council Regulation (EC). 1984. "EEC Council Regulation No. 3220/84 of 13 November 1984 Determining the Community Scale for Grading Pig Carcasses." *Official Journal of the European Union* 301: 1–3.

Daniella Jorge de Moura, Irenilza de Alencar Nääs, Elaine Cangussu de Souza Alves, Thayla Morandi Ridolfi de Carvalho, Marcos Martinez do Vale, and Karla Andrea Oliveira de Lima. 2008. "Noise Analysis to Evaluate Chick Thermal Com-

fort." *Scientia Agricola* 65 (4): 438–43. doi:10.1590/S0103-90162008000400018.

Exadaktylos, Vasileios, M. Silva, Jean Marie Aerts, C.J. Taylor, and Daniel Berckmans. 2008. "Real-Time Recognition of Sick Pig Cough Sounds." *Computers and Electronics in Agriculture* 63 (2): 207–14. doi:10.1016/j.compag.2008.02.010.

Guarino, M., P. Jans, A. Costa, J.-M. Aerts, and D. Berckmans. 2008. "Field Test of Algorithm for Automatic Cough Detection in Pig Houses." *Computers and Electronics in Agriculture* 62 (1): 22–28. doi:10.1016/j.compag.2007.08.016.

Hanton, John P., and Harley A. Leach. 1981. "Electronic Livestock Identification System."

Hemeryck, Martijn, and Dries Berckmans. 2014. "Pig Cough Monitoring in the EU-PLF Project: First Results." In *Sessions of the 65th EAAP Annual Meeting*. Copenhagen, Denmark.

Moshou, Dimitrios, Allel Chedad, A. Van Hirtum, Josse De Baerdemaeker, Daniel Berckmans, and Herman Ramon. 2001a. "An Intelligent Alarm for Early Detection of Swine Epidemics Based on Neural Networks." *Transactions of the ASAE* 44 (1): 167–74.

Moshou, Dimitrios, A. Chedad, Annemie Van Hirtum, J. De Baerdemaeker, Daniel Berckmans, and H. Ramon. 2001b. "Neural Recognition System for Swine Cough." *Mathematics and Computers in Simulation* 56 (4–5): 475–87. doi:10.1016/S0378-4754(01)00316-0.

Vandermeulen, Joris, Wilm Decré, Dries Berckmans, Vasileios Exadaktylos, Claudia Bahr, and Daniel Berckmans. 2013. "The Pig Cough Monitor: From Research Topic to Commercial Product." In *Proceedings of Precision Livestock Farming '13*, 717–23. Leuven.

Van Hirtum, Annemie. 2002. "The Acoustics of Coughing." PhD Thesis, Leuven: KU Leuven.