CHARACTERISATION OF COUGH SOUNDS TO MONITOR RESPIRATORY INFECTIONS IN PIGS

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ABSTRACT

Cough is the element for monitoring and diagnosis of respiratory disease cause of mortality and loss of productivity in pig houses. In order to prevent as much as possible the outbreak of such diseases the aim of this research is to describe acoustic features of cough sounds originating from infections due to Actinobacillosis and Pasteurellosis and to compare them with healthy cough sounds provoked by inhalation of citric acid. The acoustic parameters investigated are peak frequency [Hz], duration of cough signals. Sound analysis provides physic acoustic features that can be used as tool to detect and label cough in an automatic monitoring system applied in farms.

Keywords: cough sound, respiratory disease, Pasteurellosis, Actinobacillosis, bio-acoustics

INTRODUCTION

Respiratory pathologies, together with enteric diseases, are frequent in pig husbandry and cough is their principal symptom. The importance of these diseases must be seen on economical and sanitary level for their high veterinarian intervention costs and to a loss of profit due to higher mortality and drop of production due to reduced feed conversion and growth rate. It is also ascertained that detecting illness in individual animals and providing individual care, or group-by-group mass therapy in response to illness, are both not very effective and are costly. Due to their numerousness and incidence in farms it is crucial to investigate cough sounds with the aim of understanding respiratory diseases and use bioacoustics for real time monitoring purposes.

The importance of coughing as a means of prognosis does not refer only to humans, but also to animals. It has been shown that pig vocalisation is directly related to pain and classification of such sounds has been attempted (Marx *et al.*, 2003). It is also common practice by veterinarians to assess cough sounds in pig houses for diagnostic purposes. In this regard, there have been attempts to identify the characteristics of coughing in animals (Moreaux *et al.*, 1999, Van Hirtum, 2002a) and automatically identify cough sounds from field recordings (Aerts *et al.* 2005; Van Hirtum & Berckmans, 2003a, 2003b).

The aim of this work, by comparing different sick cough and a healthy one, is improving the labelling of coughs giving physic features to specifics sounds, those characteristics will be used as inputs in an automatic alarm system based on an algorithm that will recognize cough sounds from an installation in a farm and will provide early warning to the farmer on the welfare status of his herd. Automatic real time monitoring and early detection of these respiratory pathologies can be applied in intensive farms considering the high number of animals hosted. This can reduce the spread of the disease, save costs and provide information of how to face, in terms of bio security, the problem of prevention and spread of respiratory pathologies.

MATERIAL AND METHODS

In this work we present a comparison between cough sounds of healthy and sick animals made on a database of healthy coughs induced in laboratory conditions and sick coughs collected in field conditions in two affected pig farms fattening compartments. Both the pig farm breeding serve for the Parma ham production. The Pasteurella sick pigs, a hybrid strain Landrace x LW + Danish Duroc boar, were at the beginning of the fattening period weighing around 40 kg. The diagnosis of a veterinarian and the serologic results assured that those animals were sick, affected by pneumonia due to *Pasteurella Multocida*. The pigs suffering from infection due to *Actinobacillus Pleuropneumoniae*, were aged three months and were fattened ranged from 26–35 kg at the beginning of a cycle to reach 90–100 kg in 90 days. The genetic line was a cross between landrace Italian X Large White X Duroc. The healthy cough was induced by inhalation of citric acid in Belgian Landrace x Duroc piglets weighing between 20 and 40 kg (Van Hirtum, 2003).

For the sound acquisition 7 microphones (Monacor ECM 3005) were used with a frequency response of 50–16000 Hz, connected via preamplifiers (Monacor SPR-6) to an eight channel analogue to TDIF interface unit (Soundscape SS8IO-3). The Soundscape unit, which allows for simultaneous recording of 8 channels, was connected via a TDIF cable to a PCI audio card (Mixtreme 192). All recordings were sampled at a sample rate of 44.1 kHz with a resolution of 16 bit. All microphones were hanged in the stable. The healthy cough sounds were caused by a temporary irritation of the upper respiratory tract. On the contrary the sick ones were caused, in Pasteurellosis case, by a deep bacterial infection of the lungs since the infectious process starts at the alveolar bronchiole junction producing exudates and in the Actinobacillosis disease by a lung lesion with large red-blue areas in the upper diaphragmatic lobes with an overlying pleurisy. For recording and labelling of the cough sounds in both lab and field Adobe Audition 1.5 was used, for the signal processing Matlab 7.1 and SAS statistical package 2004 for the statistical analysis.

Analysis of the collected data

The characteristics of the cough sounds were identified in both time and frequency domain. The spectrograms of the coughs where built using a Hanning windowing function with a length of 40 ms and 20 ms overlap. The signal from the microphone was band pass filtered between 100 Hz and 10800 Hz to get rid of the low frequency noise. A comparison between healthy and sick coughs sounds have been made by considering the duration of the signal and the energy in the frequency content. The duration of a single cough, the number of hits and the time between the coughs in a cough attack were considered. This is illustrated in figure 1.

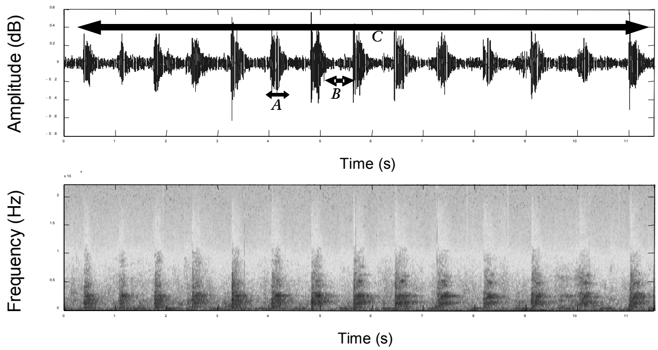

Figure 1. Pig cough attack (14 hits showed) represented in time domain (above) and in frequency domain (below).The arrows indicate the parameters studied. a) length of a cough, b) time between two cough, c) total length of the cough attack.

These parameters have been counted with auditive and visual observation on the sound spectrum by the operator using Adobe Audition program. For every cough signal the peak frequency (frequency with maximal energy content) was calculated. The analysis of variance (SAS; GLM) has been done on both the length of single coughs and cough attacks among the three classes of coughs to evaluate the certain interclasses distinction in time and frequency domain.

RESULTS

During the recording sessions we collected 851 coughs from pigs affected by Pasteurellosis and 186 coughs coming from pigs sick of Actinobacillosis coming from respectively 91 and 26 cough attacks.

The comparison made with the database of healthy coughs inducted by inhalation of Citric Acid investigated first of all the duration of the sounds

The average number of coughs in a cough attack was 13 for healthy coughs and 9 and 7 for Pasteurella and Actinobacillus ones (table 1).

The results, in terms of number of single coughs and attacks, duration, mean duration and standard deviation of the signals, are illustrated in tables 1 and table 2.

Table 1. Number of cough attacks and single coughs in the collected database

Type of cough	Nr. attacks	Nr.coughs	Min nr.coughs in attack	Max.nr. cough in attack	Mean number of coughs
Healthy	11	149	4	22	13.54
Pasteurella	91	851	5	25	9.35
Actinobacillus	26	186	3	19	7.15

Table 2. Duration of both cough attack and single sound signals, standard deviation of mean duration of single coughs

Type of cough	Mean duration attack (s)	Mean duration single cough (s)	DS single coughs
Actinobacillus	5.17	0.53	0.70
Healthy	8.61	0.43	0.13
Pasteurella	6.77	0.67	0.2

Concerning the differences in length of the three classes of single coughs and attacks investigated Variance analysis (ANOVA) was performed on the collected data using SAS statistical package (GLM procedure, 2004). The results show highly significantly differences among the classes ($P<0.001$) and lead us to consider the length of these signals as a tool to distinguish sounds. The ANOVA results among the duration of the three classes of cough attack show that the length of the coughs attack has a significantly difference between Healthy and Actinobacillus ($P<0.0387$) and between Actinobacillus and Pasteurella ($P<0.0493$) but not between Healthy and Pasteurella ($P<0.3418$).

The analysis lead over peak frequency of the single cough shows that lung diseases lower the peak frequency of the cough. There is a significant difference between peak frequency of coughs originating from Actinobacillus and Healthy cough sounds. The range for healthy coughs is between 750 Hz and 1800 Hz for peak frequency. For the two lung disorders this is between 200 Hz and 1100 Hz (table 3). The peak frequencies of Pasteurella coughs are clearly lower than healthy cough sounds (Healthy VS Pasteurella: $P>0.0062$; significant), but less significant than with Actinobacillus Pleuropneumoniae ($P > 0.0694$) (table 7; figure 2). Highly significant is also the diversity between Healthy and Actinobacillus coughs having $P> 0.00002$.

Table 3. Peak frequency mean among the three classes of single coughs

Type of cough	Peak frequency
Actinobacillus	200–1100 Hz
Healthy	750–1800 Hz
Pasteurella	200–1100 Hz

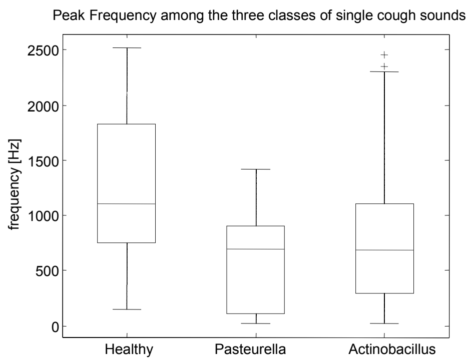

Figure 2. Boxplot of the peak frequency of the three classes of analysed coughs. The difference between the two sick coughs and the healthy one stands in a lower mean of the maximum frequency in sick coughs.

DISCUSSION AND CONCLUSION

The possibility to make a distinction between pathological and healthy cough sound by physical sound features is shown. As this work improves characterisation of the features of cough, caused by specific agents, in terms of acoustical parameters, it will be useful to improve cough sound labelling as it provides significant differences between cough arising from sick or healthy animals (Ferrari 2006, unpublished data). Literature in the past already focused on this distinction, but specifically in humans. Van Hirtum and Berckmans shown already several ways to work with pig cough, from the assessment of the cough towards vocalization (2002a), through the automated recognition of spontaneous versus voluntary cough (2002b) to the recognition of cough sound by using an algorithm for recognition in lab condition (2003a) anyway literature on acoustic features of different respiratory diseases is still unknown. In this paper sound analysis considers features like frequency energy content and duration of cough.

In terms of peak frequency of cough signal sick coughs show a significantly lower peak frequency than healthy coughs (200–1100Hz for sick and 750–1800 Hz for healthy). This is in contradiction with the findings of Korpas et al who state that frequencies of 300 Hz to 500 Hz are the most expressive in healthy human coughs whereas in cough sounds of bronchitis the bands between 500 and 1200 are the most expressive (Korpas *et al*.,1996). Sound differences in cough between humans and pigs can be explained by differences in the amount of air pushed in through the air pipe or by the dimension and characteristics of the air pipe itself. On the other hand, Van Hirtum and Berckmans (2003b) and Ferrari (2006, unpublished) showed that the fundamental frequency for healthy pig cough sounds in laboratory conditions is higher than those of sick coughs; and that's what we confirmed with our study in field conditions.

When considering the duration of a single cough, it can be seen that there is a significant difference between the two groups of cough sounds, having a mean duration of 0.53–0.67 seconds for Actinobacillus and Pasteurella, sick, coughs while 0.43 seconds was observed for healthy coughs. The trend was also observed by other authors, concluding that the duration of sick cough is longer compared to healthy one due to airways obstruction by infection and inflammation (Korpas,1996; Van Hirtum, 2002b, Ferrari 2006, unpublished data), both in humans and pigs. Concerning the duration of a single cough or a cough attack in the whole nothing is found in literature. Further analysis should be done to clarify these findings. Although a connection between the time and frequency domain characteristics and physical system parameters for pig vocalizations is not yet known, the present results indicate that such a connection exists and remains to be determined. By understanding the effect of respiratory airway inflammation and structural changes of its cell walls on cough sounds, information can be extracted about the status of the animals. Not only in laboratory conditions but also in field situations this can lead to an interesting acoustic monitoring system. The acoustics features characterizing a sick cough can be used as inputs for on-line cough counters algorithm. In this study frequency characteristics, duration of a single cough and a cough attack were compared between healthy and sick coughs. Sound analysis in field conditions provides additional, useful, non invasive objective and quantitative information about the respiratory system and is a candidate for developing automatic on-line health monitoring tool.

It is suggested that the present application integrated in an automatic detection system can be used to continuously monitor animal health and might help in advance animal welfare in pig houses.

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