CHARACTERISATION OF COUGH SOUNDS TO MONITOR RESPIRATORY INFECTIONS IN INTENSIVE PIG FARMING

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Abstract: Cough is a symptom and central element for diagnosis of very common respiratory affection causes of death and loss of productivity in intensive pig farms. The aim of this research is the comparison between acoustic features of cough sounds originating from infectious and non infectious diseases. The acoustic parameters investigated are Peak Frequency and Duration of cough signals. The differences resulting from the sound analysis confirmed variability in acoustics parameters according to a state of health or disease. Infections change the status of respiratory system; thus infectious cough (I) sounds are different than healthy ones (H). Duration of single coughs is significant different among the classes analyzed: non infectious coughs (H), Actinobacillus (A) and Pasteurella’s (P) ones. Frequency analysis allows a more general classification between H and I. Sounds can be used in an alarm system based on an algorithm to identifies automatically cough sounds and provide early warning system for the farmer about the health status of his herd.

Keywords: cough, diseases, prevention, sound

I. INTRODUCTION

Respiratory pathologies are frequent in pig husbandry and cough is their principal symptom. The importance of coughing as a means of prognosis has been shown since pig vocalisation is directly related to pain and classification of such sounds has been attempt [6]. In this regard, there have been studies to identify the characters of coughs in pigs and automatically identify them in field recordings for diagnostic purposes [1, 11, 12, 13, 14].

The following analysis considers databases of coughs collected both in field and lab condition. Two types of cough were infectious, caused by multifactorial respiratory diseases mainly caused by Actinobacillus Pleuropneumoniae and Pasteurella Multocida, the third type of cough was chemically induced in lab conditions. Actinobacillus Pleuropneumoniae is considered as a main primary bacterial agent which causes pleuropneumonia [9] whilst Pasteurella Multocida is the most important secondary one [2,8].

Actinobacillus pleuropneumoniae causes Pleuropneumonia and it currently consists of a widespread problem in intensive pig breeding farming. It interacts with Mycolplasma, Arterivirus or PCV-2. Pasteurella Multocida is an opportunist invader main cause of pulmonary pasteurellosis so often associated to Herpesvirus (PRV), Arterivirus, and Mycoplasma Hyopneumoniae. It is also cause of the progressive atrophic rhinitis, a significant cost-effective problem in the worldwide farms. Drop of production to slow death with progressive decay is typical of these diseases and prevention with strategic medical treatments is often ineffective and costs are often bigger than benefits.

The aim of this work, by comparing I and H, is improving labelling (classification) of coughs recorded giving physic values to specifics sounds that 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.

II. MATERIALS AND METHODS

A. Animals

I have been collected in two affected pig farms fattening compartments, both of them served for the Parma ham production and hosted 200 animals divided in 10 to 16 barns, in each farm. The floor was fully slatted and liquid feeding was served. The 180 Pasteurella sick pigs (40 kg) were a hybrid strain Landrace x LW + Danish Duroc boar. The serologic diagnosis (isolation in pure culture) and the necroscopic results (hypertrophic lung section with blank areas necrotic focuses and fibrinous pleurisy) assured a pneumonia due to Pasteurella Multocida associated to other infectious agents. The 200 pigs suffering from infection due to A. Pleuropneumoniae (26-35 kg) were a Italian Landrace X Large White X Duroc cross. The necroscopy showed haemorrhagic
and necrotic lung lesions. Others concurrent infections were also present.

H was induced by inhalation of citric acid (namely 0.8 moles per litre of citric acid dissolved in solution of 0.9% NaCl) in six Belgian Landrace x Duroc piglets (20-40 kg) free from respiratory diseases. These sounds have been recorded in lab conditions (for more information on this installation, and the data acquisition process see [7]).

B. Sound analysis

For I 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 8 channel Soundscape (SS8IO-3). The Soundscape unit, which allows for simultaneous recording 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.

H were caused by a temporary irritation of the upper respiratory tract caused by stimulation of the cough receptors directly resulting in coughing. On the contrary I were caused, in P case, by a deep bacterial infection of the lungs since the infectious process starts at the alveolar bronchiole junction producing exudates and in the A disease by a lung and pleurisy lesion with large red-blue areas in the upper diaphragmatic lobes with an overlying pleurisy.

The characteristics of the cough sounds were identified in both time and frequency domain. 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 has 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 Fig. 1.

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 (maximal energy content) was calculated. The analysis of variance 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. 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.

III. RESULTS

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

The average number of coughs in a cough attack was 13 for H and 9 and 7 for P and A ones (table I).

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

<table>
<thead>
<tr>
<th>Type of cough</th>
<th>Nr. attacks</th>
<th>Nr.coughs</th>
<th>Min. nr.coughs in attack</th>
<th>Max. nr. coughs in attack</th>
<th>Mean number of coughs</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>11</td>
<td>149</td>
<td>4</td>
<td>22</td>
<td>13.54</td>
</tr>
<tr>
<td>P</td>
<td>91</td>
<td>851</td>
<td>5</td>
<td>25</td>
<td>9.35</td>
</tr>
<tr>
<td>A</td>
<td>26</td>
<td>186</td>
<td>3</td>
<td>19</td>
<td>7.15</td>
</tr>
</tbody>
</table>

The results are illustrated in tables I and table II. The comparison made against the database of H investigated first of all the duration of the sounds.

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

<table>
<thead>
<tr>
<th>Type of cough</th>
<th>Mean duration attack (s)</th>
<th>Mean duration single cough (s)</th>
<th>DS single coughs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5.17</td>
<td>0.53</td>
<td>0.70</td>
</tr>
<tr>
<td>H</td>
<td>8.61</td>
<td>0.43</td>
<td>0.13</td>
</tr>
<tr>
<td>P</td>
<td>6.77</td>
<td>0.67</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Concerning the differences in length of the three classes of single coughs and attacks investigated the variance analysis results (SAS, GLM) show highly significantly differences among the classes (P<0.001). The results among the duration of the three classes of cough attack show that the length of the coughs attack has a significantly difference between H and A (P<0.0387) and between A and P (P<0.0493) but not between H and P (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 A and H cough sounds. The range for H is between 750 Hz and 1800 Hz for peak frequency. For P and A this is between 200 Hz and 1100 Hz (table III). The peak frequencies of P coughs are clearly lower than H cough sounds (H VS P: P>0.0062; significant), but less significant than with A (P > 0.0694) (table III; Fig. 2). Highly significant is also the diversity between H and A coughs having P> 0.00002.

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

<table>
<thead>
<tr>
<th>Type of cough</th>
<th>Peak Frequency Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>200-1100 Hz</td>
</tr>
<tr>
<td>H</td>
<td>750-1800 Hz</td>
</tr>
<tr>
<td>P</td>
<td>200-1100 Hz</td>
</tr>
</tbody>
</table>

Fig. 2: boxplot of the peak frequency of the three classes of analysed coughs. The representation shows the values obtained from the frequency analysis divided in quartiles, the rectangle contains the mean 50% of the distribution and the horizontal line is the median. The difference between the two sick coughs and the healthy one stands in a lower mean of the maximum frequency in sick coughs.

IV. DISCUSSION and CONCLUSIONS

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 infected or non infected animals. 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 [11] through the automated recognition of spontaneous versus voluntary cough [12] to the recognition of cough sound by using an algorithm for recognition in lab condition [14]; 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 I and 750-1800 Hz for H). This incongruous 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 500-1200 Hz are the most expressive [5]. 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 [14] and Ferrari et al. [4] showed that the fundamental frequency for non infectious pig cough sounds in laboratory conditions is higher than those of infectious coughs; our study in field conditions confirms their results.

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 s for A and P while 0.43 s was observed for H. This lead us to consider the length of these signals as a tool to distinguish sounds. The trend was also observed by other authors, concluding that the duration of infectious coughs is longer compared to non infectious ones due to airways obstruction by infection and inflammation [5, 11] both in sick 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. 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.

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 considered the controls problems due to the high number of animals hosted. This automatic approach can save medical costs and supply information of how to face, in terms of bio security, the problem of prevention and spread
of respiratory pathologies especially unavoidable diseases like the multifactor ones in intensive farms.

Dunlop [3] and Stevens and [10] stated that approximately 62% by weight of the antimicrobials have been concerned for several years about the large-scale use of in-feed antimicrobials at subtherapeutic levels in food animal production [15]. The potential risks include chemical residues in meat and the development of resistance to commonly used antimicrobials by bacteria important in human medicine. As a result, the pig industry and the regulatory bodies are attempting to limit the use of antimicrobials and encouraging improved biosecurity, management practices and vaccination policies in pig units.

Modern pork production is searching for a variety of tools to ensure health, welfare and productivity of pigs. Considering the instability of the use of antibiotics a new tools in prevention like sound analysis looks promising. Sound analysis in field conditions provides additional, non invasive quantitative informations and is candidate for developing automatic on-line health monitoring tool.

REFERENCES


used in food animal production were administered to pigs. However, consumers and regulatory authorities


