BIOACOUSTICS FEATURES AS A TOOL FOR EARLY DIAGNOSIS OF PNEUMONIA IN RIVERINE BUFFALO (*Bubalus bubalis*) CALVES

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ABSTRACT

The present study was conducted to identify specific acoustic features which could be used as possible indicators for early diagnosis of pneumonia in buffalo calves. In pneumonia, change in elasticity and resonance of vocal sound producing organs occur which eventually affects the vocal signature of calves. Twenty Murrah buffalo calves' voice was recorded during both healthy and pneumonia infected stage where pneumonia was confirmed by lung X-RAY radiography. From the recorded vocal sound, acoustic features *viz*. call duration (sec.), call interval (sec.), frequency (Hz), bandwidth (Hz) and peak amplitude (P) with their sub variants were extracted with the help of PRAAT 3.2.36 software. Out of these, call duration (sec.) (0.879±0.29 v/s 0.689±0.24), call interval (sec.) (0.288±0.059 v/s 0.107±0.047) and peak amplitude (P) (start (0.750±0.118 v/s 0.435±0.113), end (0.102±0.045 v/s 0.508±0.268) and maximum (0.938±0.210 v/s 0.684±0.480)) were found significantly ($P<0.05$) different between two groups. Rest acoustic features did not differ statistically between two groups. This study indicates that it is possible to discriminate pneumonia voice from normal/healthy voice by acoustic analysis and farmers can acquire an early warning of pneumonia infections in calves through this non-invasive method.

Keywords: *Bubalus bubalis*, buffaloes, acoustic features, calf, Murrah, pneumonia, voice

INTRODUCTION

Health care management has always been a critical and challenging issue in dairy animal production system (Wang *et al*., 2000). Diseases and calf mortality are key concerns at individual as well as organized farm level and are among major causes of economic loss in buffalo production (Sreedhar *et al*., 2010). After diarrhea, pneumonia is the second most important cause of calf mortality (25 to 27%) specially during first three months of postnatal life (Wymann *et al*.,

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2006; Zaman *et al*., 2006; Wudu *et al*., 2008). Calf pneumonia can be a significant economic burden to a farm, due to the cost of treatment, mortalities, reduced growth rates, additional labour and housing requirements (Andrews, 2000). In pneumonia normal voice patterns gets changed due to different physiological changes in vocal tract as a result of inflammatory conditions of lungs, bronchioles and pleura (Moldoveanu *et al*., 2009). Early diagnosis of respiratory diseases at farm requires regular intensive physical examination, lung auscultation and practical diagnosis supported by experience (Peek, 2005) for which continuous animal observation is basic requirement. For this, it requires substantial manpower which may be expensive and may not be available at dairy farms. Therefore, in most circumstances' animals are treated only when the infection has already developed to a late stage (Ferrari *et al*., 2008ab).

Pneumonia sound analysis might be a valuable tool for early detection of respiratory disease where pathological coughs can be a marker of infection (Exadaktylos *et al*., 2008: Ferrari *et al*., 2010). Recent developments in voice signal analysis techniques have made it possible to understand animal vocal communication (Boersma and Weenink, 2010; Taylor and Reby, 2010). In pig, considerable research has been conducted on characteristics of coughing sound (Ferrari *et al*., 2008b), the effect of environmental noise on the cough frequency features (Van Hirtum and Berckmans, 2003a), identification of pig coughing based on continuous recordings and algorithms have been developed for automatic detection of coughs (Exadaktylos *et al*., 2008a; Exadaktylos *et al*., 2008b; Van Hirtum and Berckmans, 2003b). By real time monitoring and analyzing cough sounds through bio-acoustics devices, the farmer can obtain an early warning about a developing outbreak of respiratory infections. The above assumption is based on the hypothesis that, since cough sounds are easily distinguishable from other vocalizations, it is also reasonable to assume that they might have alteration in acoustic features qualities which can be identified by sound recording, labeling and analytic procedures (Van Hirtum and Berckmans, 2002a). The aim of present study was to investigate the differences between voice's acoustic features of pneumonia affected calves and normal calves in order to identify specific auditory cues to diagnose pneumonia symptoms in early stage of development.

MATERIALS AND METHODS

Location of study

Study was conducted at Livestock Research Centre (LRC) of ICAR-National Dairy Research Institute (NDRI), Karnal, Haryana, India. Geographically NDRI is situated at an altitude of 2530 meters above the mean sea level (Indo-Gangetic alluvial plains) between 29.69^o North latitude and 76.99^o East longitude. The annual rainfall is about 760 to 960 mm, most of which is received during July and August. The climate of Karnal is sub-tropical and temperature may reach extremes in winter (-2^{o}C) and summer (45^{o}C).

Selection and management of calves

Initially thirty-five Murrah buffalo (*Bubalus bubalis*) calves with age group of ten to thirty days (Mean±S.D., 18.23±6.77 days), showing early sign of respiratory distress were selected for voice recording from the Livestock Research Centre. These infected calves were selected and followed till their complete recovery phase to record their voice in both stages (infected and recovered). Calves were screened out for the confirmation of pneumonia (n=20) using clinical symptoms and x-ray radiography and were used for studying change in vocal signature. X-Ray for confirmation of pneumonia infection was done by qualified veterinary surgeon at regional station of Lala Lajpat Rai University of Veterinary and Animal Sciences, Uchani, Karnal, Haryana, India. Figures 1 and 2 shows X-Ray of pneumonia affected and healthy/ recovered calf, respectively.

The duration of study was from October, 2015 to February, 2016. Infected calves were kept separately in a loose housing system including covered and open area (BIS standards, 2005). The dimension of each individual calf shed was 2 m × 1 m. The ratio of open and covered area of each individual shed was 50:50; were kept loose in these sheds, as they are normally maintained at Livestock Research Centre. Feeding of calves was done as per NRC (2001) recommendations. All the other routine management practices were performed as per followed by livestock research center without any interference. The whole research work protocol was duly approved by Animal Ethics Committee of National Dairy Research Institute.

Recording and processing of voice signals

Sound recording of individual calf was done in their individual pens at fixed hours between 7.00 am to 9.00 am during calm and silent hours of day. Their voice was recorded for an enough period so that we could get at least 30 clips per day from the total recording of each calf. Sound recording was performed by using Sony HDV FX7E, handicam equipped with a good quality microphone (Sony ECM674, mono-directional). The microphone was placed near the front wall of fence at a height of 100 cm. from floor, while the video camera was on a tripod at suitable height and distance in such a position so that it could capture each voice signal of the calf under recording and did not disturb natural behaviour of calf. The recorded voice signals were then transferred to computer by plugging in it with video camera. Precautions were taken so that the animals did not get disturbed by these measuring devices and environment. The recorded sound signals were then transferred to a computer. All the superimposed and other environmental sound signals were detected and eliminated manually by observing the spectrogram of each signal during editing by using Adobe Premium Pro-1.5 audio-visual editing software. Sound signals were resampled at a sampling frequency of 48 kHz and 16 bits. To extract defined set of features, only a small window of voice signal was processed at a time. Voice signals of calves were broken into short frames of 15 milli seconds using a hamming window to get stationary signal characteristics. Following eight acoustic features were extracted with the help of PRAAT 5.1.36 software package (Boersma and Weenink, 2010).

a. Call duration (sec)

b. Call intervals (sec)

c. Minimum frequency (Hz) - start, maximum and end

d. Maximum frequency (Hz) - start, maximum and end

e. Peak frequency (Hz) - start, maximum and end

f. Fundamental frequency - start, maximum and end

g. Band width (Hz) - start, maximum and end

h. Peak amplitude (P) - minimum, maximum and mean

The data thus obtained was arranged in

appropriate way on MSEXCEL sheet for statistical analysis.

Statistical analysis

The statistical analysis was carried out at the computer center of the research institute. The data were analyzed by using least squares technique (Harvey, 1987) and Paired t-test assuming equal variance was applied for comparison of changes in acoustic features during both situations. Following least squares model was used to examine the significant differences between the different acoustic features of voice signals uttered by individual calf.

$$Yij = \mu + Pi + eij$$

Where, Yij is the acoustic feature of voice signals; i^{th} calf; μ is the overall mean; Pi is the effect of i^{th} pneumonia stage on voice of calf; and eij is the residual error ~ (μ, σ2).

RESULTS AND DISCUSSION

In present study, acoustic features of vocal sound from pneumonia affected calves and healthy calves were compared which are presented in Table 1. Out of total extracted acoustic features, three features i.e., call duration (sec.), call interval (sec.)

Table 1. Mean±S.E. of various acoustic features of healthy (recovered) calves and pneumonia affected calves.

S. No.	Acoustic features	Healthy (recovered) calves	Pneumonia affected calves
1	Call duration (sec.)	$0.879^{a}\pm0.29$	$0.689^{b}\pm0.24$
2	Call interval (sec.)	$0.107^{b}\pm0.047$	$0.288^{a}\pm0.059$
3	Peak frequency (start) (Hz)	2770±883.24	2788.15±631.39
4	Peak frequency (end) (Hz)	1243.33±1.12	1226.73±0.99
5	Peak frequency (max) (Hz)	4034.943±1027.85	3435.53±610.21
6	Minimum frequency (start) (Hz)	645.49±233.04	668.42±148.28
7	Minimum frequency (end) (Hz)	1087.71±457.50	1125.45±480.27
8	Minimum frequency (max) (Hz)	1576.20±452.46	1137.50±476.54
9	Maximum frequency (start) (Hz)	2577.59±69.06	2163.15±374.24
10	Maximum frequency (end) (Hz)	1326.20±58.73	1108.52±51.23
11	Maximum frequency (max) (Hz)	2585.76±28.63	3621.55±56.25
12	Fundamental frequency (start) (Hz)	574.39±190.33	597.36±180.06
13	Fundamental frequency (end) (Hz)	1247.04±45.09	1141.39±53.92
14	Fundamental frequency (max) (Hz)	1258.20±53.80	1275.68±55.49
15	Bandwidth (start) (Hz)	502.68±155.47	477.63±81.98
16	Bandwidth (end) (Hz)	256.48±56.44	276.89±131.0
17	Bandwidth (max) (Hz)	645.23±132.73	568.42±841.46
18	Peak amplitude (start) (P)	$0.750^{a}\pm0.118$	$0.435^{b}\pm0.113$
19	Peak amplitude (end) (P)	$0.1022^{a}\pm0.045$	$0.508^{b}\pm0.268$
20	Peak amplitude (max) (P)	$0.938^{a}\pm0.21$	$0.684^{b}\pm0.48$

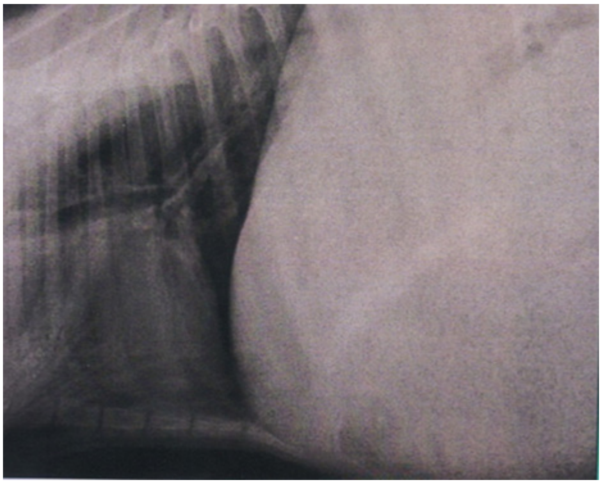

Figure 1. X-Ray radiograph of pneumonia affected calf.

Figure 2. X-Ray radiograph of pneumonia recovered calf.

Figure 3. Vocal waveform of pneumonia affected calf voice.

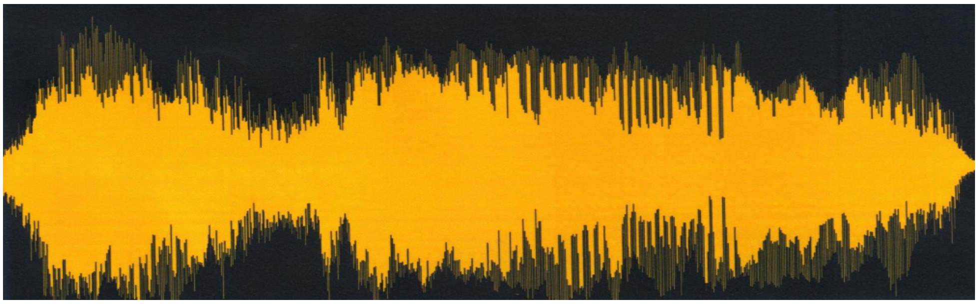

Figure 4. Vocal waveform of healthy or normal calf voice.

and peak amplitude (P) varied significantly ($P<0.05$) between infected calves and recovered calves. Call duration (sec.) (0.879±0.29 v/s 0.689±0.24) and peak amplitude (start) (0.750±11.80 v/s 0.435±11.35), peak amplitude (maximum) (0.938±21.53 v/s 0.684±48.36) and peak amplitude (end) (0.102±20.52 v/s 0.508±26.80) were found to be significantly higher ($P<0.05$) in healthy (recovered) group as compared to infected group, respectively. While call interval (sec.) was found statistically ($P<0.05$) higher in infected group as compared to normal group (0.288±0.059 v/s 0.107±0.047).

Vocal Waveforms in Figures 3 and 4 is showing differences between both groups i.e. pneumonia affected calves and healthy (recovered) calves respectively. By just seeing these figures, we can differentiate healthy and infected sound waves, more frequent peaks have been observed in healthy calf sound due to more energetic state of amplitude. Comparison of frequency (Hz), bandwidth (Hz) acoustic features was found non-significant ($P>0.05$) between the groups. Although following parameters such as bandwidth (start, max, end) fundamental frequency (start), minimum frequency (start, max, end) and peak frequency (max) values were lower in healthy calves but did not differ statistically from infected calves. While parameters such as fundamental frequency (end, max), maximum frequency (start, max, end) and peak frequency (start, end) values were lower in infected calves but no significant difference was observed between groups because of changes in oscillation patterns of vocal folds. In this study, acoustics features like call duration, call intervals and peak amplitude have been found relevant to objective of identifying infected sound and these three features are typical for each class of sound (Van Hirtum and Berckmans, 2002; Ferrari *et al*., 2008a, 2008b). Similar studies have been conducted in the past in animals to demonstrate the changes in voice signals during several respiratory infections (Korpas *et al*., 1987, 1993; Robertson and Benzie, 1989; Van Hirtum and Berckmans, 2003a; Aerts *et al*., 2005; Ferrari *et al*., 2008a, 2008b). Duration of call decreased in infected sound which may be due to swelling and inflammatory condition of vocal tract and lungs, which leads to the accumulation of fluid in trachea while in healthy cases the inflammation is absent in lungs and vocal passage is clear. The duration of a sound represents starting point of sound wave from increasing amplitude state to decreasing or silent state and it has been found significantly ($P<0.05$) higher in healthy calf group indicating healthy source of voice production (lungs). The call interval was significantly higher in infected calf as compared to healthy calves. The longer call interval may be due to painful and inflammatory condition of vocal tract at the time of infection. Our findings were found in agreement with Ferrari *et al*. (2008b) in pigs, Ferrari *et al*. (2010) in calves. Amplitude (depicts sound pressure level) was found significantly ($P<0.05$) higher in healthy group as compared to infected group which indicates more energetic expenditures by healthy calves because amplitude is considered as an honest indicator of voice quality, condition of animal (Russell *et al*., 1998). Bioacoustics studies has started to focus on developing and testing algorithms for automatic cough detection from real time continuous recording of sound of animals (Van Hirtum and Berckmans, 2002, 2003b; Guarino *et al*., 2004; Jans *et al*., 2004; Exadaktylos *et al*., 2008b). Therefore, it can be said that cough sound during pneumonia may be a useful biomarker in respiratory diseases diagnosis in dairy buffalo calves. Further, by monitoring and analyzing cough sounds through automatic devices, farmer can obtain an early clue about developed outbreak of respiratory diseases.

CONCLUSION

This study explores the possibility that bioacoustics analysis may be a useful tool to discriminate healthy and infected calves sounds. Differences in acoustic features like call duration, call interval and peak amplitude have proved to be useful acoustic indicators of pneumonia in Murrah buffalo calves. Still more comprehensive study is required for early diagnosis of respiratory diseases by use of vocalization as a non-invasive technique.

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