Broiler Vocalisation to Predict the Growth

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Abstract

The constantly growing yearly demand for meat, dairy products and eggs has important implications for agricultural production methods. Nowadays livestock/crop production is becoming increasingly industrialised worldwide, shifting from extensive, small-scale, subsistence production systems towards more intensive, large-scale, geographically-concentrated, specialised and commercially oriented ones.

The shift in livestock farming methods from extensive to intensive poses a number of significant challenges for animal welfare, environmental sustainability and food security.

The indicators to assess animal's health and welfare status, have been increased during the last years, and the importance of this discipline is now widely known worldwide. Thanks to the welfare quality® protocol the procedure to assess the animal health and welfare has become more and more clear, precise and accurate since the project ended in 2009.

Furthermore this procedure to assess animal welfare status is time consuming and requires manpower and accurate planning.

One way to make easier and faster this assessment could be the application of audio and video analysis. These techniques have been using widely and for long time to better identify specific behaviours and vocalisation patterns in different animals' species.

Chicken broiler vocalisations, for instance, have been studied for many years in order to better understand the vocal pattern of this species in relation to environmental temperatures and situations of stress (e.g. high/low temperatures).

Automatic animal monitoring should be a method to support farmers in achieving farm sustainability. Precision Livestock Farming (PLF) can combine audio and video information into automated tools serving as early warning systems for the farmer when health or welfare problems are detected.

PLF can also be used to aid the management of some complex biological production processes, for example in food strategies, to control the growth rate and to monitor the animal activity.

Using tools to continuously monitor and quantify animal behaviour, vocalisations and production, allow farmers to act as suitable.

In general, the reliability of PLF is determined primarily by the animal and all the physiological variables that can/must be continuously measured, such as weight, activity, behaviour, food intake, noise produced, body temperature, heart or respiratory rate, etc. Continuous measurement means that, depending on the variable in question, the frequency of measurements must be high/elevated. Other requirements include the capability to provide reliable prediction and, along with on-line measurement, integration of the algorithms that are necessary for automatic animal monitoring in order to implement correct control strategies.

Through the application of process engineering, Precision Livestock Farming (PLF) can combine audio and video information into on-line automated tools that can be used to control, monitor and model the behaviour, the health and production of animals and their biological response.

One of the objectives of PLF is to develop on-line tools for monitoring farm animals continuously and automatically during their life. the objective is to measure criteria calculated on-line from collected data without imposing additional stress to the animals. Besides on-line automatic monitoring, Precision Livestock Farming (PLF) also offers possibilities in automated control for supporting the management of such complex biological production processes.

The aim of this study was to record and analyse broiler vocalisations under normal farm conditions, to identify the relation between animal sounds and growth trend.

Recordings were made at regular intervals, during the entire life of birds, in order to evaluate the variation of frequency and bandwidth of the sounds emitted for the whole cycle of production.

The final goal of this study wants to be the development of an automated growth monitoring tool.

Two experimental trials were carried out in an indoor reared broiler farm, with 27940 chicken broilers inside; the entire audio recording procedures lasted for 38 days. The recordings were made at regular intervals from day 1 to day 38 and it was also kept the same position of the equipment, during each period of data collection, in to the broiler house.

Animal sounds were recorded for 1 continuous hour using 2 different microphones during each experimental session from day 1 to day 38. The first microphone has been placed above pan feeders, at an average height of 40 cm from the animals, in order to record individual and localised small group sounds. The second one was placed above the drinkers , at an average height of 40 cm in order to record sounds coming from that area.

Once a week, 50 birds were selected at random and their weight recorded in order to follow the growth trend in the birds.

These specific recording procedures were realised in a completely automated, non-invasive and non-intrusive way and especially without disturbing the animals in to the shed.

Sound recordings were manually analyzed and labelled using a sound analysis software: Adobe Audition CS6. Every one hour long recorded digital file was cut in shorter files of 10 minutes duration in order to make the sound analysis easier. Sound labelling involved the extraction and classification of both individual animal sounds and sounds coming from the whole flock on the basis of the amplitude or frequency of the sound signal in audio files recorded at farm level.

Analysing the sounds recorded, it was possible to find a significant correlation ($P<0.001$) between the frequencies of the vocalisations recorded and the weight of the broilers, during the different experimental trials.

The results explained how the frequency of the sounds emitted by the animals, were inversely proportional to the age and the weight of the broilers; specifically the more they grow, the lower the frequency of the sounds emitted by the animals is.

This preliminary study shows how this method based on the identification of specific frequencies of the sounds emitted by the animals, in an indoor reared broiler farm, linked to their age and weight, could be able to be used as an early warning method/system to evaluate the health and welfare status of the animals at farm level.

Introduction

The constantly growing yearly demand for meat, dairy products and eggs has important implications for agricultural production methods. Nowadays livestock/crop production is becoming increasingly industrialised worldwide, shifting from extensive, small-scale, subsistence production systems towards more intensive, large-scale, geographically-concentrated, specialised and commercially oriented ones [18].

Nowadays more than 40 billion chickens are produced annually all over the world by highly specialised industries. Broilers are the fastest-growing farmed species hatched and reared under intensive farm condition in flocks of about 10,000-30,000 birds [20, 5]. Chicken performance is influenced by ambient temperature, relative humidity, air quality and air ventilation speed, thus adequate ventilation is required. Growth, performance, health and welfare depend on proper management and for this reason poultry has attracted greater levels of animal welfare concern than any other farm animal [16].

The shift in livestock farming methods from extensive to intensive poses a number of significant challenges for animal welfare, environmental sustainability and food security [17].

The number of available indicators which can be used to assess animal's health and welfare status, have been increased during recent years, and the importance of animal welfare assessment science as a discipline is now recognised worldwide.

Thanks to the Welfare Quality® protocol, a procedure to assess the animal health and welfare has become more widely applied since the project ended in 2009.

However, assessor based procedures to assess animal welfare status are time consuming and require manpower and accurate planning. One possible way to make animal welfare assessment easier and faster could be the application of audio and video analysis. Animals use vocalisations to express different inner states provoked either internally or by external events, and also to reveal some of their behavioural needs. It is reasonably easy and feasible to record animals' vocalisation, and for these reasons vocalisations should be considered as a potential indicator of animal health and welfare [13]. Bioacoustics is the study of acoustic characteristics and biological significance of sounds emitted by living organisms [16] it is a cross-disciplinary science which investigates sound production, dispersion and reception in biological organisms [9] to evaluate conditions such as stress and welfare through, for example, calls and vocalisations [7, 18].

These techniques have been used widely to better identify specific behaviours and vocalisation patterns in different animals' species. For instance chicken broiler vocalisations have been studied [14] in order to better understand the vocal pattern of this species in relation to environmental temperatures and situations of stress (e.g. high/low temperatures).

As reported by [12] animal vocalisations can be a useful tool to assess animal comfort, being a precise and objective technology. The non-invasive nature of the equipment means that it can be used for long-term monitoring of animals without disturbing them [3].

Precision Livestock Farming (PLF)

Automatic animal monitoring could potentially be used to support farmers in achieving farm sustainability. Precision Livestock Farming (PLF) can combine audio and video information into automated tools serving as early warning systems for the farmer when health or welfare problems are detected. One of the objectives of PLF is to develop on-line tools for monitoring farm animals continuously and automatically during their life without imposing additional stress to the animals. PLF may also be used to aid the management of some complex biological production processes or to measure the growth rate and to monitor the animal activity [10, 11, 18].

The PLF approach can be applied to different aspects of management, with a focus on the animals and/or on the environment, and at different scales, from the individual to the entire flock/herd [19].

In general, the reliability of PLF is determined primarily by the animal and then by the physiological variables that can/must be continuously measured, such as weight, activity, behaviour, food intake, noise produced, body temperature, heart or respiratory rate. Continuous measurement means that, depending on the variable in question, the frequency of measurements must be high or at least regular. Other requirements include the capability to provide reliable prediction and, along with on-line measurement, integration of the algorithms that are necessary for automatic animal monitoring in order to implement the correct control strategies.

Through the application of process engineering, Precision Livestock Farming (PLF) can combine audio and video information into on-line automated tools that may be used to control, monitor and model the behaviour, the health and production of animals and their biological response [18].

Aim of the work

The aim of this study was to record and analyse broiler vocalisations under normal farm conditions, to identify the relation between animal sounds and growth trends. Recordings were made at regular intervals, during the entire life of broiler birds, in order to evaluate the variation of frequency and bandwidth of the sounds emitted for the whole cycle of production. The final goal of this study aims to be the development of an automated growth monitoring tool.

Material and methods

Two experimental trials were carried out in an indoor reared broiler farm; the first one took placed in June and July 2013 and the second one in August and September 2013.

The farm where the experimental trials took place was an indoor broiler farm rearing birds to the RTFA (ACP) standard. The house dimensions were 61m x 21m and the total floor area available to the birds was 1,130m^2. Inside the house there were 2,340 nipples drinkers, and 385 feed pans available to birds. 27,940 day old chicks were placed inside the house at day 1 in both trials.

Sound recordings were collected using a professional handheld solid state recorder (Marantz PMD 661 MK II) which was connected to two different directional microphones placed at an intermediate height of between 0.4m and 0.8m (depending on the height of the animals in order to keep the same distance among animals and microphones during the entire data-collecting procedure).

The supercardioid/lobe microphone (Mic. 1) was a Sennheiser K6 / ME66" (frequency response: 40-20,000Hz ± 2,5 dB) and it was held by a short tripod microphone stand (Quiklok A341) above the feeder.

The (cardioid) microphone (Mic. 2) was a Sennheiser K6 / ME64" (frequency response: 40-20,000Hz ± 2,5 dB) and it was placed on a long tripod (Quiklok A492 Heavy-Duty Boom Mic Stand) directly above the drinkers.

Both the microphones were slightly inclined toward the floor in order to capture preferentially the sounds coming from the birds walking exactly in front of the microphone axis.

The recordings provided a sound image of background noise, and gave a better idea of what was happening overall inside the broiler house.

The Marantz PMD 661 MK II recording machine had a large range of potential recording settings. The settings found to give the most sensitivity to bird sounds in the poultry house environment were:

Rec. Format: PCM-16, Stereo Sample Rate: 44.1k

Level Control.: Manual Low Cut: Off High Cut: Off

Animal sounds were recorded for 1 continuous hour using 2 different microphones during each experimental session from day 1 to day 38. Recordings were made at regular intervals every Monday, Wednesday and Friday, with the same position of the equipment along the trial procedures.

Once a week, 50 birds were selected at random and their weight recorded in order to follow the growth changes in the birds. Throughout the production period from day 1 to day 38 house temperature and humidity levels were recorded.

The entire data collection consisted in 16 days of sound recordings for trial 1, 15 days of sound recordings for trial 2, and 6 weekly weight collections for both trials.

In total 55 h 20 min of recordings were collected and 600 birds were weighted during trial 1 and trial 2; only the audio files recorded in conjunction with the weight collection of the birds were included in the data analysis.

In total 600 sounds (50 sounds per day), chosen at random and selected from 12 days of recordings were manually labelled and analysed in this study.

Sound analysis

Sound recordings were manually analyzed and labelled using sound analysis software: Adobe® Audition™ CS6. Every hour long duration recorded digital file was cut into shorter files of 10 minutes duration in order to make the sound analysis easier.

Sound labelling involved the extraction and classification of both individual animal sounds and general sounds coming from the whole flock on the basis of the amplitude and frequency of the sound signal in audio files recorded at farm level [18].

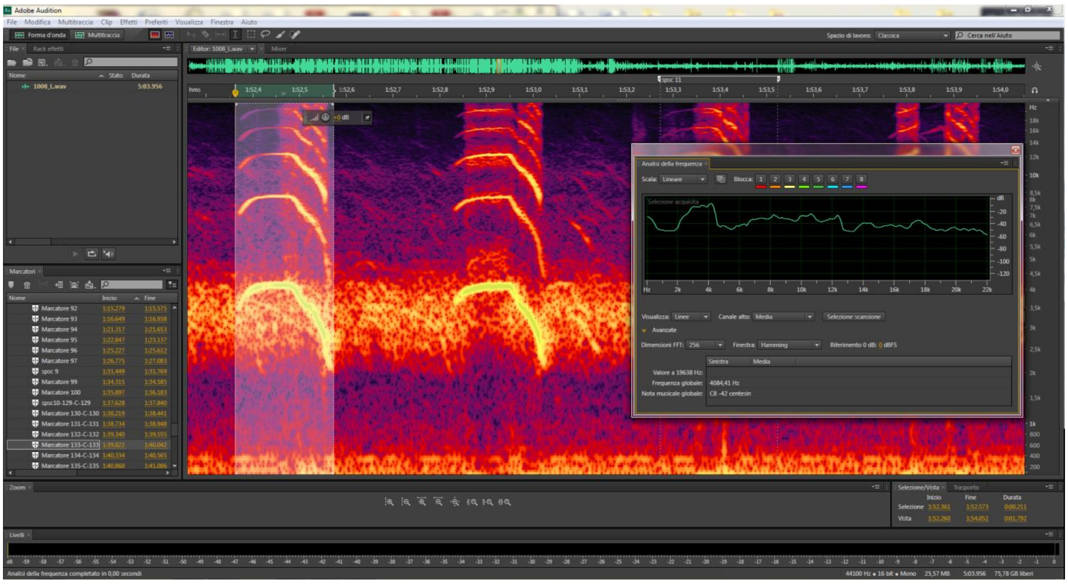
Labelling is a manual procedure based on acoustic analysis combined with visual spectral analysis, which is used to extract pieces of sounds from the entire recording file. The labelling procedure was done offline extrapolating those sounds that the operator classified as significant vocalisation sounds through the auditive analysis and the visual observation of the spectrogram of the sounds as well [7].

Through Adobe® Audition™ CS6 [1] each sounds were identified and analysed using time (x-axis) and frequency (y-axis).

The Fast Fourier Transform (FFT) was used to perform the frequency analyses using a Hamming window with a FFT dimension of 256 (Figure 1).

For each sound the peak frequency (PF= representing the frequency of maximum power) was manually extracted. The frequency range was band pass filtered between 1,000 Hz to 13,000 Hz. The lower frequency limit was set at 1,000 Hz to remove the low frequency background noise and the upper limit was set at 13,000 Hz to cut off the high frequency noise and also because broilers are sensitive to a frequency range of about 60 to 11,950 [4, 6, 16].

Figure 1. Screenshot of the Adobe® Audition ™ software showing the spectrograms and the frequency analysis window relative to a specific vocalisation.



Statistical analysis

Differences among PF extracted from the 600 sounds recorded in the two trials were tested with the PROC TTEST of SAS 9.3 [15]. A paired t-test was performed to compare PF of sounds recorded at different ages of birds within the same trial.The relation between weight and PF of sounds recorded at different ages was also investigated with PROC CORR in SAS 9.3.The PROC REG. was used to predict variation in the PF according to the change of age of the birds (in weeks) with the following model:

$$PF= week$$

The estimation of effects influencing the PF was performed with the GLM procedure in SAS 9.3. The model used was the following:

$$PF= weight*age$$

Table 1. Description of the fixed effect Weight*age used in the GLM model. The 12 classes, are the result of the interaction of the age with the average weight of the birds.

Weight (g)	Age (d)	Weight*age	Weight (g)	Age (d)	Weight*age
40.72	1	1	1,039.46	22	7
44.56	1	2	1,092.84	23	8
198.64	8	3	1,529.00	29	9
231.42	9	4	1,731.60	30	10
550.30	15	5	2,104.28	36	11
608.66	16	6	2,275.44	37	12

The fixed effect (weight*age) was divided in 12 classes, as the result of the interaction of the age with the average weight of the birds (Table 1). The division in classes allowed to avoid the nesting effect.

Results and discussion

The weights collected during the two experimental trials are reported in table 2:

Table 2. Chicken Broilers weight collected during their entire life, both in trial 1 and trial2.

	Trial 1			Trial 2		
WEEK	**Day of Rec**	**N of animals**	**Mean ± SD (g)**	**Day of Rec**	**N of animals**	**Mean ± SD (g)**
1	1	50	44.56 ± 1.5	1	50	40.72 ± 4.9
2	8	50	198.64 ± 10.1	9	50	231.42 ± 1.1
3	15	50	550.3 ± 21.7	16	50	608.66 ± 26.7
4	22	50	1,039.5± 68.6	23	50	1,092.84± 74.4
5	29	50	1,529± 120.5	30	50	1,731.6± 130.3
6	36	50	2,104.28± 208.5	37	50	2,275.44± 247.0

For each sound the frequency analysis was carried out, in order to extract the peak frequency of each vocalisation. The mean weights collected during both trials agree with the growth trend of this breed found in literature (Aviagen, 2012).

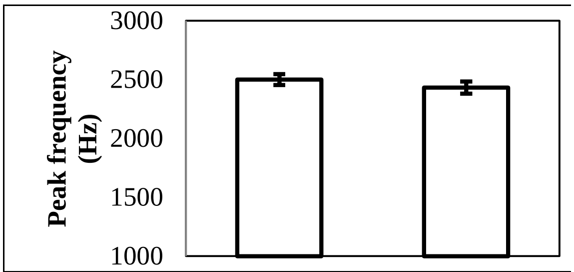
Table 3 shows the means and standard deviations of the peak frequency (PF) of sounds recorded in trial 1 and trial 2.

Table 3. Means and standard deviations of the peak frequency (PF) of the sounds recorded in both trials.

	Trial 1			Trial 2		
WEEK	**Day**	**N os sounds**	**Mean ± SD (Hz)**	**Day**	**N of sounds**	**Mean ± SD (Hz)**
1	1	50	3,545± 365	1	50	3,621 ±402
2	8	50	3,059 ±459	9	50	2,953 ± 353
3	15	50	2,618 ±360	16	50	2,474 ± 384
4	22	50	2,329 ± 605	23	50	1,955 ± 520
5	29	50	1,943 ± 569	30	50	1,902 ± 585
6	36	50	1,506 ±434	37	50	1,475 ± 493

The comparison between trials (Figure 2) shows how there is no difference (P value= 0.4508) between PF mean of the sounds recorded in both trials.

Figure 2. Comparison between PF means of the sounds recorded in trial 1 and in trial 2.

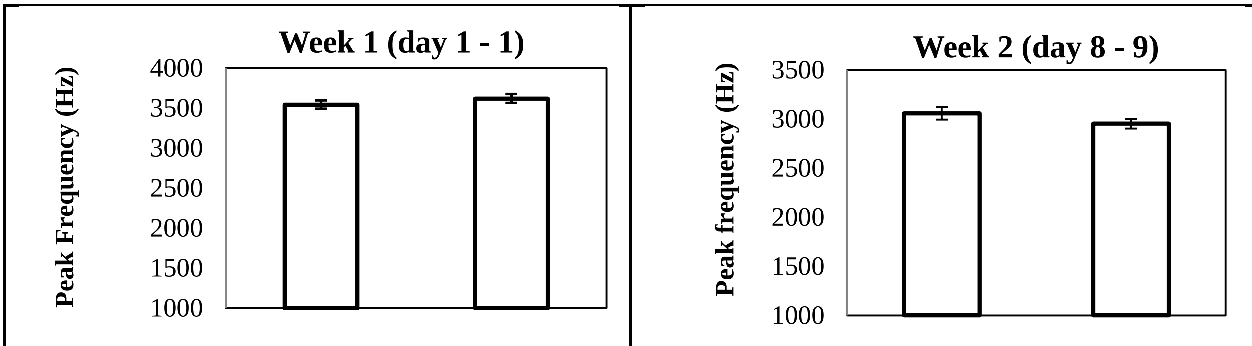


Trial	1	2
Mean	2,500	2,432
Std err	48	52
Significance	P= 0.4508, ns	

Furthermore, the comparison between PF of sounds collected on the same week of age of birds during the experimental trials (Figure 3) confirmed that the two trials could be considered the same. This could be related to the use in poultry farming of fast-growing hybrid broilers with typical and homogeneous growth rate across production cycles.

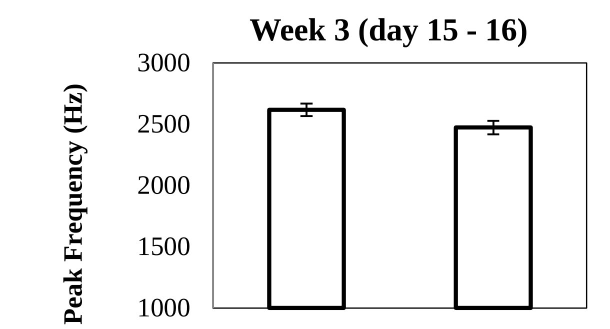
Indeed all the P values reported in Fig 3 reveal the non-significant difference between PF means of the sounds emitted by the animals during specific days of both trials.

Figure 3. Comparison between PF means of sounds emitted during days of the same week of age recorded in different trials.

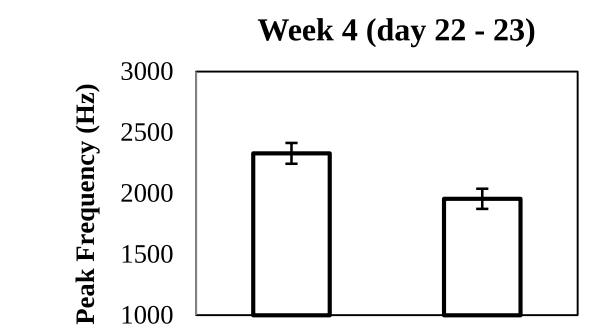


Trial	1	2
Mean	3,545	3,621
Std err	52	57
Significance	P= 0.3257, ns	

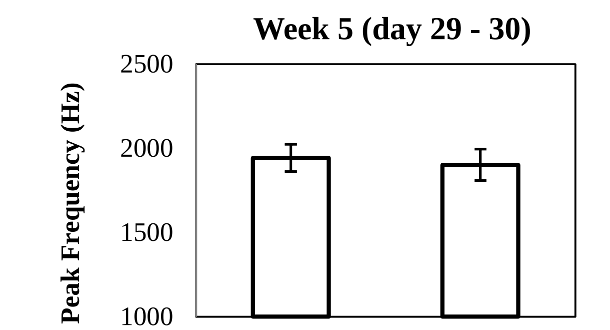
Trial	1	2
Mean	3,059	2,952
Std err	65	50
Significance	P= 0.0688, ns	



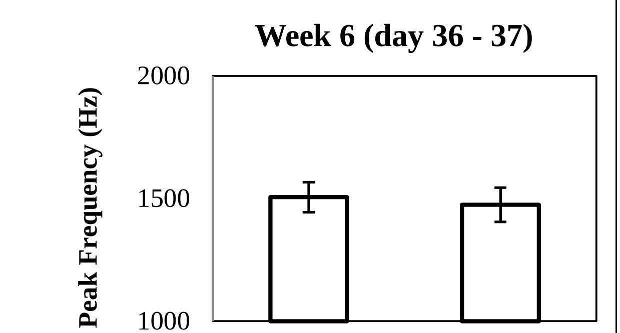
Trial	1	2
Mean	2,618	2,474
Std err	51	54
Significance	P= 0.6535, ns	



Trial	1	2
Mean	2,329	1,955
Std err	86	82
Significance	P= 0.3277, ns	



Trial	1	2
Mean	1,943	1,902
Std err	80	93
Significance	P= 0.8496, ns	



Trial	1	2
Mean	1,505	1,475
Std err	61	70
Significance	P= 0.3783, ns	

In Table 4 and Table 5 the paired T-test between days of the same trial were tested to verify the difference between the PF means of the vocalisation during the life of the broiler chickens; the difference is resulted significant in both trials

As it is possible to see in Table 4 and Table 5 and in Figure 3 each age is characterised by its own typical peak frequency that decreases with the growth of the birds.

Considering the difference between week 1 and week 6 it is possible to see how the peak frequency decreases of about 2,000 Hz.

In both trials the average frequency reduction was around 350 Hz per week.

Furthermore analysing the PF related to the weight of birds, it was possible to confirm a significant negative correlation (-0.80; P<0.0001) between the frequencies of the vocalisations recorded and the weight of the broilers, during the different experimental trials.

Table 4. Paired T-test between different days to verify the difference between the PF means of the vocalisations during the entire life of the broiler chickens in trial 1.

Trial 1

Comparison		Difference			
Between days within the trial 1	N	Min	Max	Mean (SEM)	P-value
Day 1 – Day 8	50	-861.3	1,378.1	485.8 (76.7)	<.0001
Day 1 – Day 15	50	0	2,411.7	926.8 (66.9)	<.0001
Day 1 – Day 22	50	0	2,928.5	1,216.2 (103.8)	<.0001
Day 1 – Day 29	50	0	2,756.3	1,602.1 (93.3)	<.0001
Day 1 – Day 36	50	-172.3	3,100.8	2,039.6 (94.3)	<.0001
Day 8 – Day 15	50	-344.5	2,239.5	441.0 (72.2)	<.0001
Day 8 – Day 22	50	-861.3	2,411.7	730.4 (106.8)	<.0001
Day 8 – Day 29	50	-344.5	3,617.6	1,116.3 (108.4)	<.0001
Day 8 – Day 36	50	516.8	3,789.8	1,553.8 (85.5)	<.0001
Day 15 – Day 22	50	-861.3	1,722.7	289.4 (91.5)	<.0001
Day 15 – Day 29	50	-861.3	2,239.5	675.3 (100.7)	<.0001
Day 15 – Day 36	50	-172.3	2,411.7	1,112.8 (81.8)	<.0001
Day 22 – Day 29	50	-1,722.7	1,894.9	385.9 (124.8)	0.003
Day 22 – Day 36	50	-516.8	2,067.2	823.4 (101.5)	<.0001
Day 29 – Day 36	50	-1,378.1	1,722.7	437.6 (101.7)	<.0001

Table 5 Paired T-test between different days to verify the difference between the PF means of the vocalisations during the entire life of the broiler chickens in trial 2.

Trial 2

Comparison		Difference			
Between days within the trial 2	N	Min	Max	Mean (SEM)	P-value
Day 1 – Day 9	50	-344.5	2,067.2	668.4 (73.4)	<.0001
Day 1 – Day 16	50	-689.1	2,411.7	1,174.3 (87.69)	<.0001
Day 1 – Day 23	50	-172.3	2,928.5	1,674.1 (121.4)	<.0001
Day 1 – Day 30	50	344.5	3,273.1	1,740.3 (120.7)	<.0001
Day 1 – Day 37	50	344.5	3,273.1	2,146.4 (80.8)	<.0001
Day 9 – Day 16	50	1,205.9	1,722.7	478.9 (79.4)	<.0001
Day 9 – Day 23	50	-861.3	1,894.9	949.7 (96.6)	<.0001
Day 9 – Day 30	50	-344.5	3,617.6	1,015.9 (109.0)	<.0001
Day 9 – Day 37	50	0	2,239.5	1,478.0 (80.6)	<.0001
Day 16 – Day 23	50	-1,033.6	1,722.7	485.9 (102.2)	<.0001
Day 16 – Day 30	50	-1,033.6	2,067.2	552.1 (107.2)	<.0001
Day 16 – Day 37	50	-516.8	2,411.7	999.1 (97.1)	<.0001
Day 23 – Day 30	50	-1,205.9	2,067.2	366.3 (136.4)	0.03
Day 23 – Day 37	50	-1,378.1	2,239.5	428.5 (137.0)	0.0034
Day 30 – Day 37	50	1,378.1	1,550.4	362.2 (130.6)	0.0085

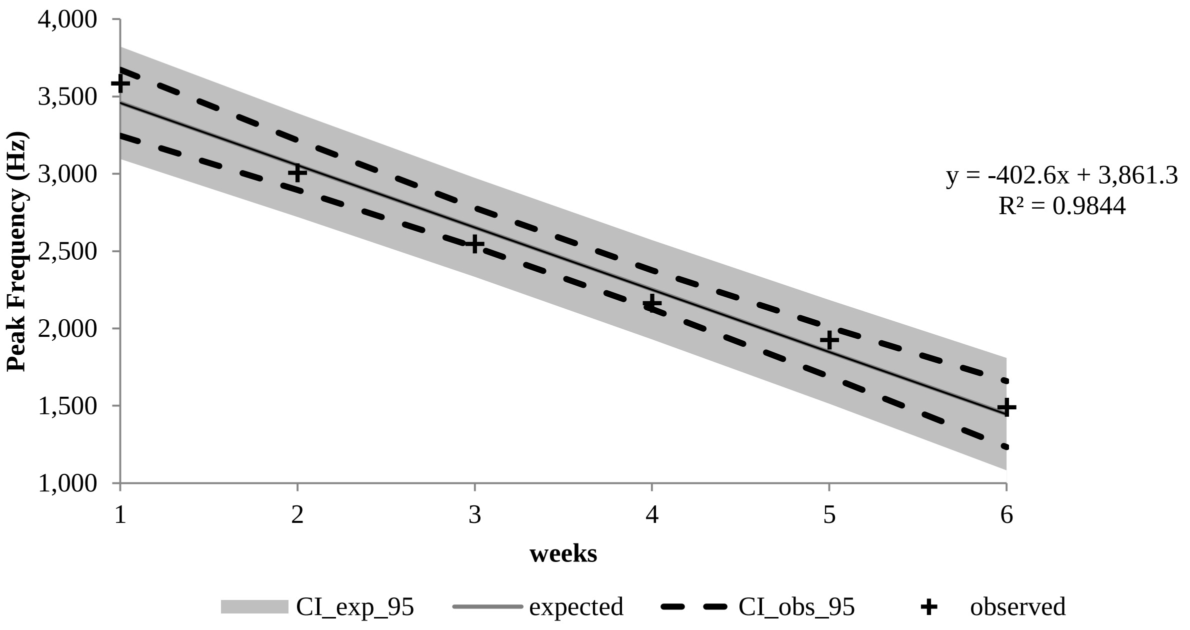
As it is shown in Figure 4 the peak frequency of the vocalisations of the broiler chickens is strictly dependent on the age and on the weight of birds.

The regression model is significant (F=251.52, P <0.0001), indicating that the model accounts for a significant portion of variation in the data. The R^2 indicates that the model accounts for 98% of the variation in peak frequency.

The confidence interval (CI_obs_95) of the observed values shows a 95% probability that the true linear regression line of the population will lie within the confidence interval of the regression line calculated from the sample data.

The confidence interval (CI_exp_95) that includes the expected values of the regression model with a probability of 95% (grey area in Fig 4) indicates the goodness of fit of the regression model.

Figure 4. Linear regression of PF in relation to the age of the animals expressed in weeks. Confidence intervals of the mean are reported in dotted lines. Confidence intervals of the prediction are represented by the grey area.

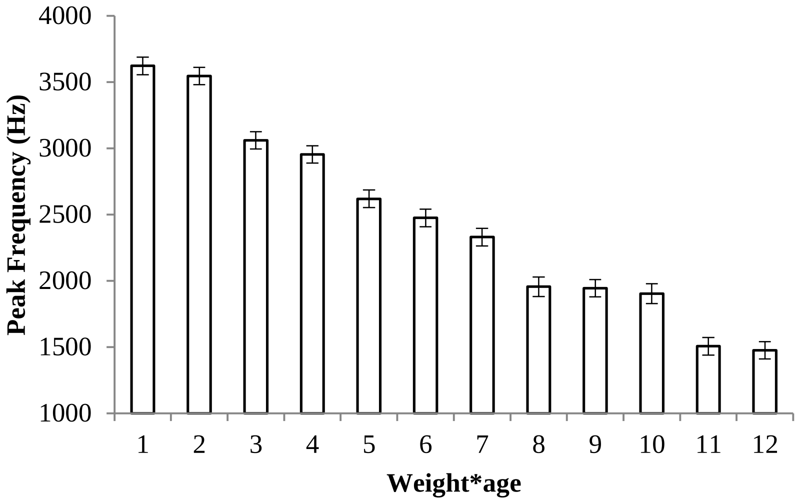


The results of the GLM were useful to verify the high impact of the weight and the age of the birds on the PF of the vocalisation emitted by the animals during their life. In Figure 5 are reported the LSMEANS(± SEM) of the PF of vocalisations according to the increase of the age and weight of the animals.

There is a decrease of peak frequency in vocalisations according to the age of the broiler chickens.

As reported by [14] the PF of the vocalisation emitted by one week old chicks ranged from 3,000 to 4,000 Hz reinforcing the results of the present study that very young chicks vocalise at high frequency under non-stress condition.

Figure 5. LSMEANS(± SEM) of the peak frequency of vocalisation according to the increase of age and weight. P < .0001



Conclusion

The results indicate that the peak frequency of the sounds emitted by the animals, is inversely proportional to the age and the weight of the broilers; specifically the more they grew, the lower the frequency of the sounds emitted by the animals. This preliminary study shows that this methodological approach, based on the identification of specific frequencies of sound emitted by the animals, in an indoor reared broiler farm, linked to their age and weight, could be used as an early warning method/system or a continuous monitoring system to evaluate the health and welfare status of the animals at farm level. Furthermore, this strict correlation between weight of the birds and peak frequency of the sounds emitted by the animals could open the scenario to an automated tool based on vocalisation to predict the weight and the growth trend of the birds.

Of course further studies, in different farms, with daily data collection are necessary to improve the knowledge on the relationship between vocalisation and weight of birds in order to create an accurate weight prediction algorithm based on sounds emitted by the animals.

Acknowledgement

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