IDENTIFICATION OF ACOUSTIC PARAMETERS FOR BROILER WELFARE ESTIMATE

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ABSTRACT: Estimates of broiler welfare have subjective character. Nowadays, researchers seek non-invasive features or indicators that may describe this condition in animal production. The aim of this study was to identify acoustic parameters to estimate broiler welfare using the following five vocalization acoustic parameters: energy, spectral centroid, bandwidth, first formant, and second formant. The database that generated the model was obtained from a field experiment with 432 broilers, which half were Cobb® and half, Ross® breed, from day 21 to 42, containing bird vocalizations under either welfare or stress conditions. The results of the experiment generated responses to the tested conditions of gender, genetic strain, and welfare. The proposed model was based on the specific response of mean weights for each situation of stress and well-being. From the results, a model was developed to estimate the welfare condition of broilers from the registered information linked to their vocalization.

KEYWORDS: signal analysis, broiler production, algorithm.

IDENTIFICAÇÃO DE PARÂMETROS ACÚSTICOS PARA ESTIMATIVA DE BEM-ESTAR DE FRANGOS DE CORTE

RESUMO: A estimativa do bem-estar de frangos de corte tem caráter subjetivo, e, hoje, pesquisadores buscam características ou indicadores não invasivos que possam caracterizar esta condição na produção animal. O objetivo deste trabalho foi identificar parâmetros acústicos que possam ser utilizados na estimativa de bem-estar de frango de corte. Cinco parâmetros acústicos da vocalização foram testados: energia, centroide espectral, largura de banda, primeira formante e segunda formante. A base de dados utilizada proveio dos resultados de um experimento de campo, em que foram utilizadas 432 aves, metade da linhagem Cobb® e a outra da linhagem Ross®, do 21º ao 42º dia, contendo vocalizações em estado de bem-estar e sem este. Os resultados do experimento geraram respostas para as condições testadas de sexo, linhagem genética e condição de bem-estar. Os pesos médios específicos das respostas, em cada situação de estresse e bem-estar, foram utilizados para propor uma estimativa da situação de bem-estar. A condição de bem-estar dos frangos de corte pôde ser identificada em função de sua vocalização, pela energia do sinal acústico e das formantes 1 e 2, e em função da origem genética das aves.

PALAVRAS-CHAVE: análise de sinais, produção de frangos de corte, algoritmo.

INTRODUCTION

Objective estimates of conditions that promote either welfare or stress to animals are not easy tasks. Many features in the animal welfare field may change when considering race, gender, age, feeding, management, and individual characteristics of each animal (BROOM & FRASER, 2007; FRASER, 2009). On the other hand, welfare indicators should be studied together with a set of measurements, so that it can appropriately reflect the animal state (SPINKA, 2012). Animal welfare can be estimated with objective indicators, such as measure of glucocorticoids (RAULT, 2012); subjective indicators can also be used, such as aggressive behavior, presence of lesions, and

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analysis of vocalization and images (BROOM & FRASER, 2007; BAKER et al., 2012; NÄÄS et al., 2012).

Vocalization is an indicator that can be obtained without interfering in the animal behavior, providing parameters that can estimate welfare and, therefore, being an effective indicator of animal welfare (MANTEUFFEL & SCHÖN, 2004; NÄÄS et al., 2008; RANDALL et al., 2009).

Mathematical models have been used to estimate animal welfare using pattern recognition (NÄÄS et al., 2008; SHAO & XIN, 2008; DAWKINS et al., 2009; NÄÄS et al., 2012). Among the natural patterns expressed by animals, vocalization is one of the most important means of information transmission, so the acoustic monitoring can provide an efficient management tool to improve animal health and welfare (JAHNS, 2008).

This study aimed to develop a theoretical model for estimating welfare conditions of broilers as a function of their vocalization. We also investigated whether there were different responses according to gender and genetic strain.

METHODOLOGY

For the identification of acoustic parameters, which formed the development basis of the theoretical model, data from field experiments were used.

Field experiment for data recording on broiler vocalization

This experiment used 432 broilers, which half were Cobb®, and half, Ross® breed. Birds were monitored during production from day 21 to 42, as commonly applied in commercial broiler farms. The study was conducted under similar commercial conditions in the experimental avian area at the College of Agricultural Sciences, Federal University of Grande Dourados, Mato Grosso do Sul State, Brazil. Broilers were housed in eight pens, with litter thickness of 5 cm of rice husk. The temperature inside the experimental aviary was maintained at 18-24 ºC, and light regime was 12:12h (light:darkness).

Broilers were separated into boxes by genetic strain and gender. There were four boxes with Cobb® individuals, that is, two boxes with females and two with males. For Ross® broilers, the same division was applied. Animals were then divided into two groups, A and B, with 44 and 64 broilers, respectively; there were males and females of each genetic strain in each group.

For group A, five degrees of animal welfare freedom were applied (BROOM & FRASER, 2007; MENDL et al., 2009; SILVA et al., 2009). Birds from group B were exposed to some stress, for instance, they were reared under high density (> 30 kg m^{-2}), and both water and fodder were not offered *ad libitum*.

Records of sound signals occurred in the boxes in two periods of the day, morning and afternoon. Vocalizations were recorded along 2 min using a unidirectional microphone with high frequency response coupled to a digital recorder.

Sound analysis

From the signals recorded during bird vocalizations, 10 s of each vocalization were randomly chosen, and analyzed using Praat® and Matlab® softwares. Four vocalization acoustic parameters were extracted: energy (E), bandwidth (Bw), first formant ($F1$), and second formant ($F2$). These acoustic parameters were used to identify whether broilers were under welfare or stress conditions.

Energy is the energy amount emitted by a sound source; it can be calculated using [eq.(1)]:

$$\mathbf{E} = \int_A \left[\int_0^{\Delta t} \mathbf{I_s}(\mathbf{r}, \mathbf{t}) \mathbf{dt} \right] \mathbf{dA} \tag{1}$$

where,

I_s - acoustic intensity as a function of the point chosen in time, and
dt - represents the time period that sound energy is measured.

Spectral centroid can be defined as the mass center of each frame power spectrum (THEODORIDIS & KOUTROUMBAS, 2006), and is calculated using eq.(2):

$$Ce(i) = \frac{\sum_{k=1}^{K} k.\,|X_i(k)|^2}{\sum_{k=1}^{K} |X_i(k)|^2} \quad (2)$$

where,

$X_i(k)$ - components of the Discrete Fourier Transform of a known frame i , and

k - half of the number of spectral components used in the Discrete Fourier Transform.

Bandwidth is a measurement of the frequency band width of a signal, in Hertz, which can be calculated using eq.(3):

$$Bw_i = \sqrt{\frac{\sum_{k=1}^{K} [(Ce_i - k)^2 \quad |X_i(k)|^2]}{\sum_{k=1}^{K} |X_i(k)|^2}} \quad (3)$$

where Ce_i represents the spectral centroid.

Formants of a noise signal shall be considered as a kind of sound source identity, and can be defined as the peak energy of a limited region of a given sound spectrum. Therefore, the extraction of this acoustic parameter provides a better characterization of bird vocalizations. After extraction of the acoustic parameters, thresholds were established based on international and national standards, following the various conditions found in the field.

During data collection, the sounds were recorded in four replications for each stress and welfare situation. Student t-test and F-test with 95% significance were applied to the data to verify differentiation of stress and welfare conditions between both genetic strains and genres.

RESULTS AND DISCUSSION

The theoretical model, which was based on individual weights under each stress and welfare condition and extraction of acoustic parameters, was initially drawn for the possible variables that influence the decision flow statement of the theoretical model (Figure 1).

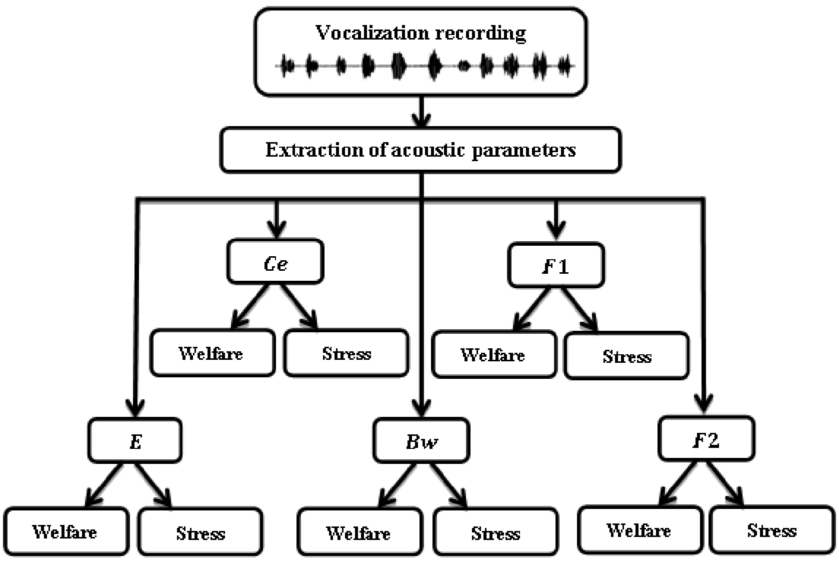

FIGURE 1. Flux diagram of the proposed theoretical model to estimate broiler welfare condition.

Based on data recorded from the bird vocalizations, we calculated the waveforms of the sounds emitted by broilers during conditions of thermal heat stress (≥ 30 ºC) and neutral ambient, which was considered as welfare (24 °C). Frequency spectra among Cobb® (Figure 2) and Ross® (Figure 3) females and Cobb® (Figure 4) and Ross® (Figure 5) males were different.

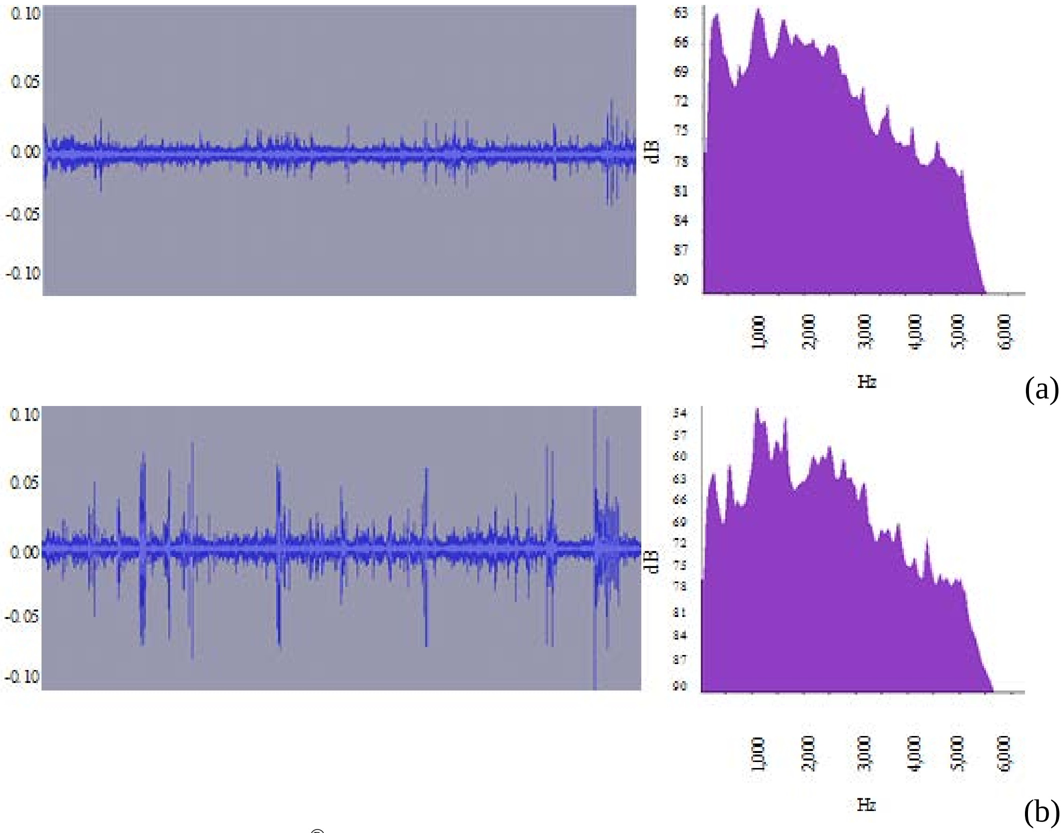

FIGURE 2. Vocalization of Cobb® female during welfare (a) and stress (b) conditions.

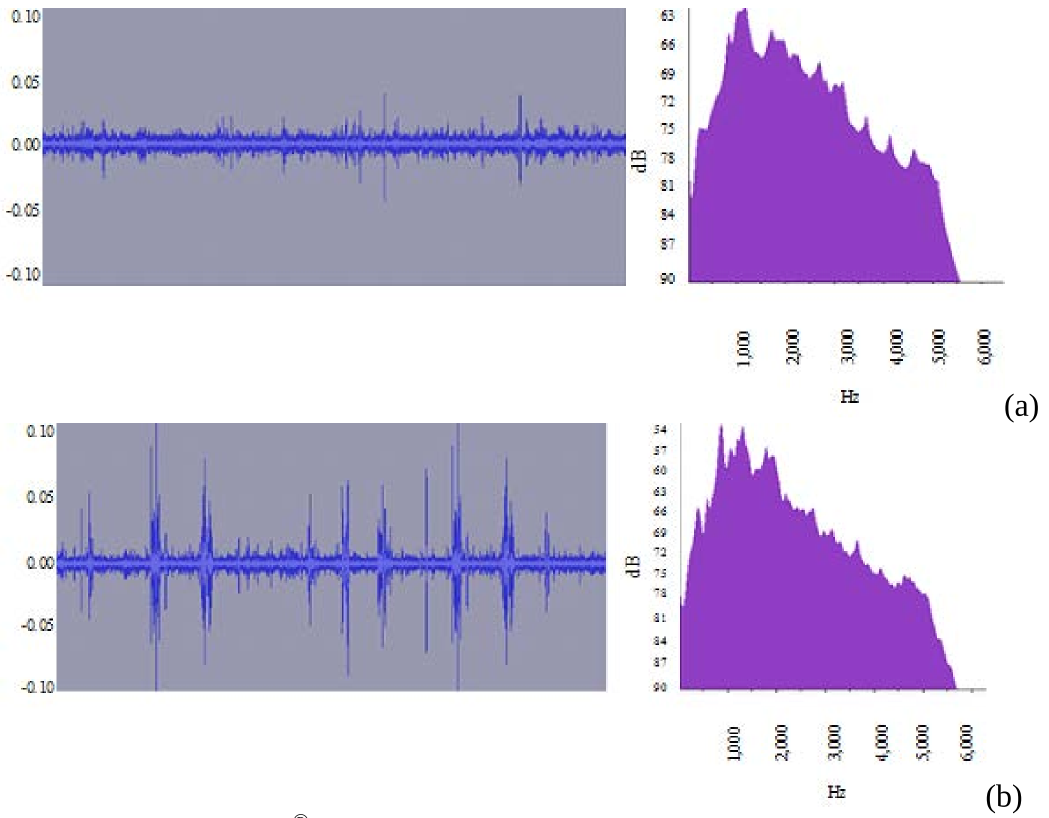

FIGURE 3. Vocalization of Ross® female during welfare (a) and stress (b) conditions.

Differences of wave shapes and vocalization frequency of broilers between both genetic strains show that individuals respond with different vocalization according to heat stress exposure. The response differed also according to their gender. Reports in the literature indicate differentiation in acoustic signals of vocalizations between males and females (CERIT & AVANUS, 2007; GEBERZAHN et al., 2009), while other authors highlight that vocalization different responses may be an indicator of lack of welfare, i.e., stress (BRUMM et al., 2009; KOKOLAKIS et al., 2010; BAKER et al., 2012), corroborating the results of this study.

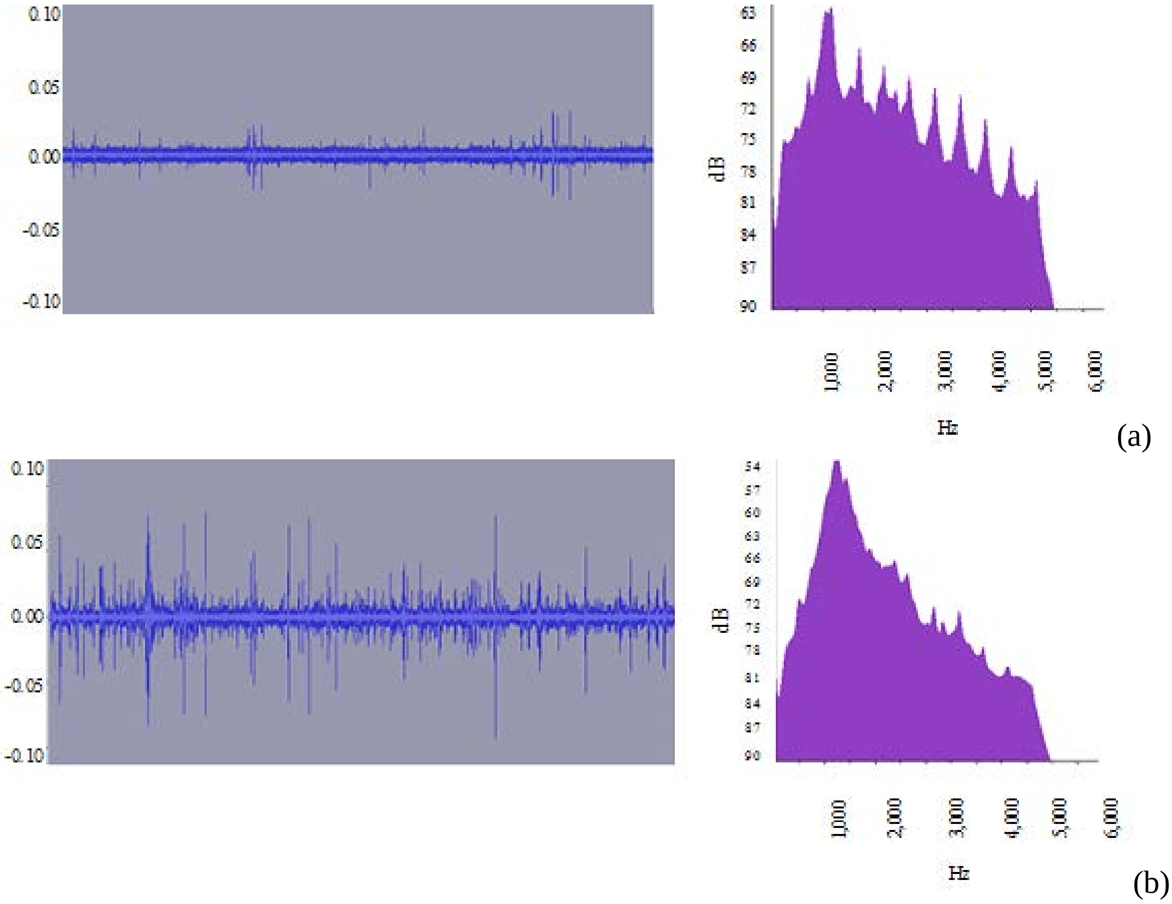

FIGURE 4. Vocalization of Cobb® male during welfare (a) and stress (b) conditions.

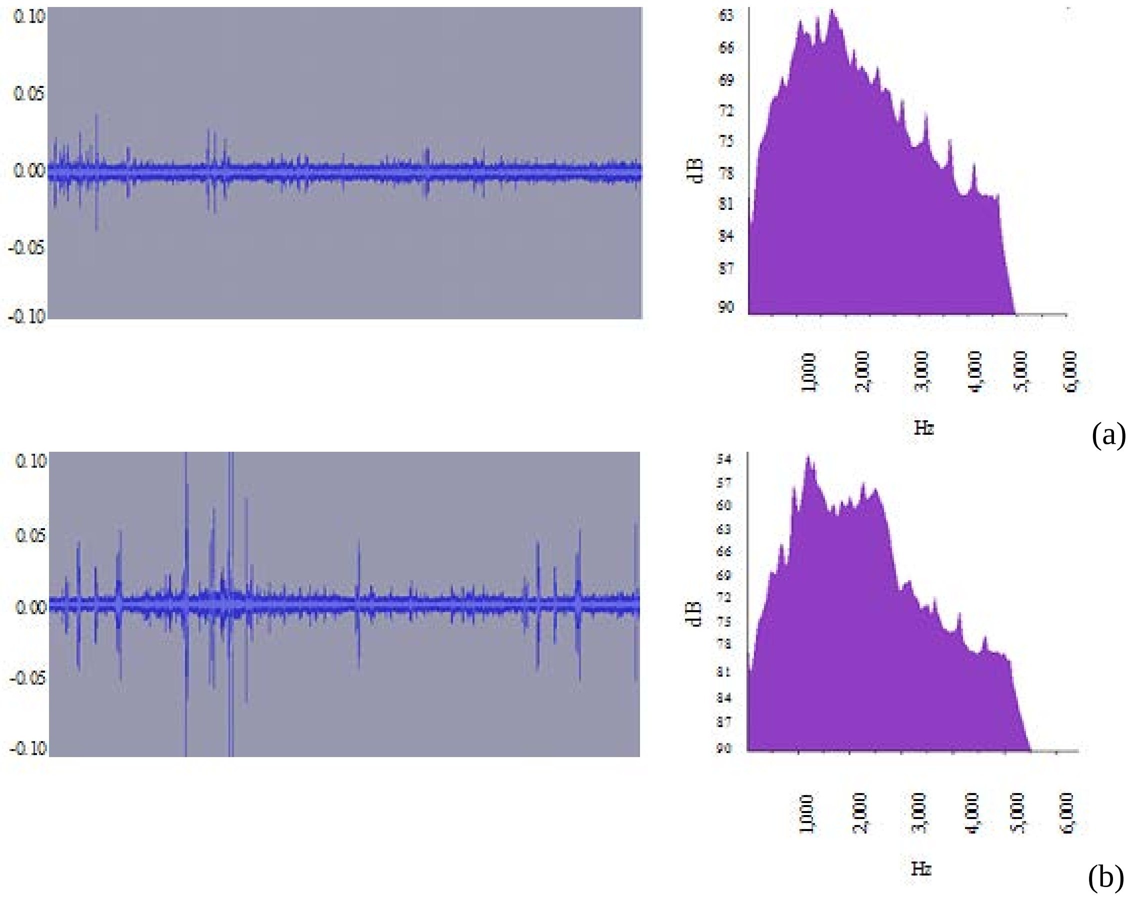

FIGURE 5. Vocalization of Ross® male during welfare (a) and stress (b) conditions.

We also observed that there was a difference between wave shapes and vocalization frequency of male broilers depending on genetic strain, what indicates that vocalization during welfare conditions was also different from that response obtained during thermal stress exposure. According to BROOM & FRASER (2007), studies that analyze animal behavior must be carefully planned to obtain reliable conclusions, which were found in this experiment, as sounds were recorded in four replications for each stress and welfare situation. Only three parameters showed different values after the application of Student t-test and F-test (Table 1). Therefore, for final algorithm implementation, only three parameters with P-values $\leq$ 0.05 were used (CREUTZIG et al., 2010), which were energy, formant 1 and formant 2.

TABLE 1. Statistical results for differentiation of stress and welfare conditions between two genetic strains.

Genetic strain	Parameter	P-value	
		F-test	Student t-test
Cobb®	*E*	NS	NS
	Bw	NS	NS
	F1	0.005	NS
	F2	0.002	NS
Ross®	*E*	NS	$8.549\ E^{-07}$
	Bw	NS	NS
	F1	NS	NS
	F2	NS	NS

NS = non-significant.

A theoretical model was proposed based on the stress and welfare conditions observed during this study, which considers the mean weight values for the acoustic parameters extracted from broiler vocalizations (Figure 6). Other authors have also used the standard features, resulting from field experiments, to implement a model (JAHNS, 2008; SHAO & XIN, 2008 and DAWKINS et al., 2009).

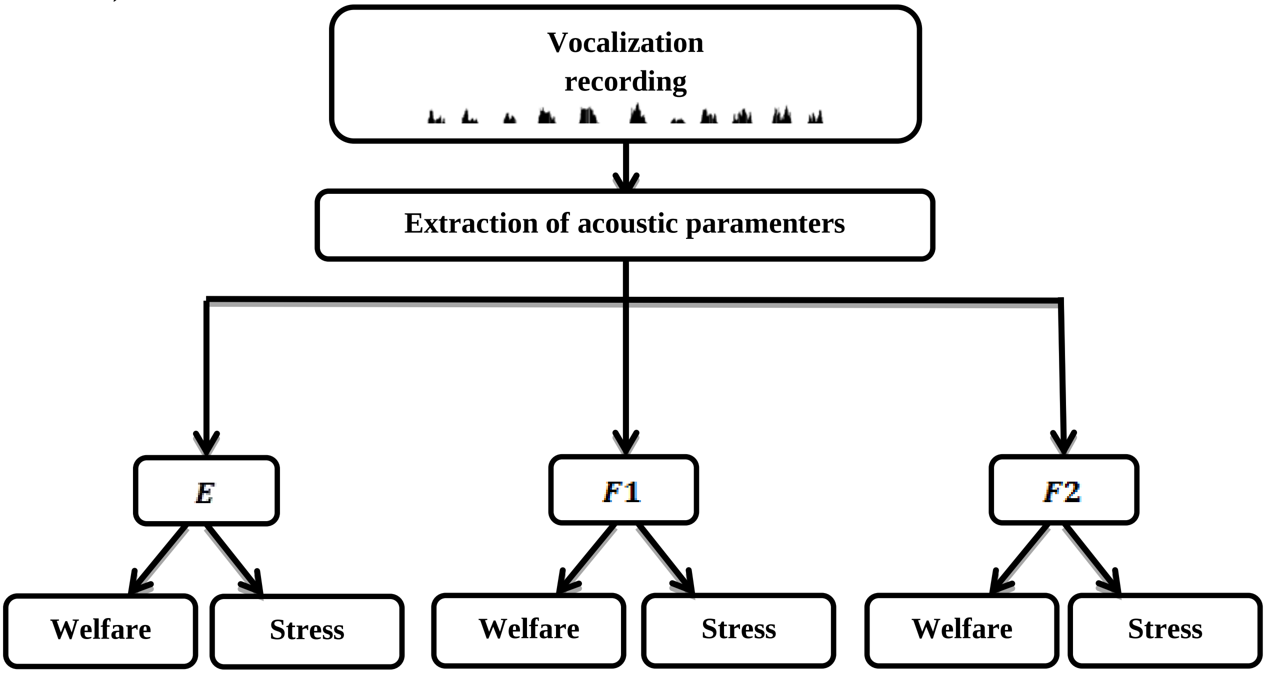

FIGURE 6. Flux diagram of the developed theoretical model to estimate broiler welfare condition.

To determine welfare and stress conditions, the individual mean weight for acoustic parameters extracted for each condition (Table 2) was considered (CHAN et al., 2011). The mean values for the extracted parameters from the vocalizations are presented in e Table 3.

TABLE 2. Description of the situation for welfare condition determination.

If	The mean acoustic parameters extracted from the vocalizations is higher than or equal to the value found for each parameter	Then	The broiler is not under welfare conditions.
If	The mean acoustic parameters extracted from the vocalizations is lower than the value found for each parameter	Then	The broiler is under welfare conditions.

TABLE 3. Statistical results for differentiation of stress and welfare conditions between two genetic strains.

Parameter (unit)	Value
E (kcal)	0.00110
F1 (Hertz)	1,094.321
F2 (Hertz)	1,104.709

The reference signals of stress and lack of welfare are linked to fear, hunger, and frustration. Audible warning signals are not produced by reflection, but when individuals are exposed to stress (MENDL et al., 2009; KOKOLAKIS et al., 2010). Another important aspect is that male and female birds perceive risk differently from each other (CERIT & AVANUS, 2007; VOLODIN et al., 2009); therefore, the response to lack of welfare, such as imminent risk factors, may be different for each gender.

CONCLUSIONS

Using the acoustic parameters energy (E), bandwidth (Bw), first formant ($F1$), and second formant ($F2$), which differed according to the studied genetic strain and gender, it was possible to suggest a theoretical model; its implementation may help estimates of welfare conditions for broilers.

REFERENCES

BAKER, T. M.; WILSON, D. R.; MENNILL, D. J. Vocal signals predict attack during aggressive interactions in black-capped chickadees. *Animal Behaviour*, Amsterdam, v. 84, n 4, p. 965-974, 2012.

BROOM, D. M.; FRASER, A. F. Welfare assessment. In: BROOM, D. M.; FRASER, A. F. *Domestic animal behaviour and welfare*. Wallingford: CABI Publishing, 2007. p.58- 69.

BRUMM, H.; SCHMIDT, R.; SCHRADER, L. Noise-dependent vocal plasticity in domestic fowl. *Animal Behaviour*, London, v.78, n.3, p.741-746, 2009.

CERIT, H.; AVANUS, R. Sex identification in avian species using DNA typing methods. *World's Poultry Science Journal*, Cambridge, v. 63, n. 1, p. 91-99, 2007.

CHAN, W. Y.; CLOUTIER, S.; NEWBERRY, R. C. Barking pigs: differences in acoustic morphology predict juvenile responses to alarm calls. *Animal Behaviour*, Amsterdam, v. 82, n. 4, p.767-774, 2011.

CREUTZIG, F.; BENDA, J.; WOHLGEMUTH, S.; STUMPNER, A.; RONACHER, B.; HERZ, A. V. M. Timescale-invariant pattern recognition by feed forward inhibition and parallel signal processing. *Neural Computation*, Berlim, v. 22, n. 6, p.1493-1510, 2010.

DAWKINS, M. S.; LEE, H-J.; WAITT, C. D.; ROBERTS, S. J. Optical flow patterns in broiler chicken flocks as automated measures of behaviour and gait. *Applied Animal Behaviour Science*, Amsterdam, v. 119, n. 3-4, p.203-209, 2009.

FRASER, D. Animal behaviour, animal welfare and the scientific study of affect. *Applied Animal Behaviour Science*, Amsterdam, v.118, n. 3-4, p. 108-117, 2009.

GEBERZAHN, N.; GOYMANN, W.; MUCK, C.; TEN CATE, C. Females alter their song when challenged in a sex-role reversed bird species. *Behavioral Ecology and Sociobiology*, Springer, v.64, n. 2, p.193-204, 2009.

JAHNS, G. Call recognition to identify cow conditions - A call-recogniser translating calls to text. *Computers and Electronics in Agriculture*, Amsterdam, v. 62, n. 1, p. 54-58, 2008.

KOKOLAKIS, A.; SMITH, C.L.; EVANS, C. S. Aerial alarm calling by male fowl (*Gallus gallus*) reveals subtle new mechanisms of risk management. *Animal Behaviour*, London, v.79, n.6, p. 1373-1380, 2010.

MANTEUFFEL, G.; SCHÖN, P. C. Measuring pig welfare by automatic monitoring of stress calls. *Bornier Agratechnische*, Bericht, v.29, n. 1, p.110-18, 2004.

MENDL, M.; BURMAN, O. H. P.; PARKER R. M. A.; PAUL, E. S. Cognitive bias as an indicator of animal emotion and welfare: Emerging evidence and underlying mechanisms. *Applied Animal Behaviour Science*, Amsterdam, v.118, n.3-4, p.161-181, 2009.

NÄÄS, I. A.; CAMPOS, L. S. L.; BARACHO, M. S.; TOLON, Y. B. Uso de redes neurais artificiais na identificação de vocalização de suínos. *Engenharia Agrícola*, Jaboticabal, v.28, n.2, p.204-216, 2008.

NÄÄS, I. A.; LAGANÁ, M. V.; MOLLO, M. N.; CANUTO, S.; PEREIRA, D. F. Image analysis for assessing broiler breeder behavior response to thermal environment. *Engenharia Agrícola*, Jaboticabal, v.32, n.4, p. 624-632, 2012.

RANDALL, D.; OWREN, M. J.; MICHAEL J.; RYAN, M. J. What do animal signals mean? *Behaviour*, Brill, v.78, n.2, p.233-240, 2009.

RAULT, J-L. Friends with benefits: Social support and its relevance for farm animal welfare. *Applied Animal Behaviour Science*, Amsterdam, v. 136, n. 1, p. 1-14, 2012.

SHAO, B.; XIN, H. A real-time computer vision assessment and control of thermal comfort for group-housed pigs. *Computers and Electronics in Agriculture*, Amsterdam, v. 62, n. 1, p. 15-21, 2008.

SILVA, R. B. T. R.; NÄÄS, I. A.; MOURA, D. J. Broiler and swine production: animal welfare legislation scenario. *Scientia Agricola*, Piracicaba, v.66, n.6, p. 713-720, 2009.

SPINKA, M. Social dimension of emotions and its implication for animal welfare. *Applied Animal Behaviour Science*, Amsterdam, v.138, n. 3-4, p.170-181, 2012.

THEODORIDIS, S., KOUTROUMBAS, K. *Pattern recognition*. 3rd ed. London: Academic Press, 2006.

VOLODIN, I.; KAISER, M.; MATROSOVA, V.; VOLODINA, E.; KLENOVA, A.; FILATOVA, O.; KHOLODOVA, M. The technique of noninvasive distant sexing for four monomorphic *dendrocygna* whistling duck species by their loud whistles. *The International Journal of Animal Sound and its Recording*, London, v.18, n. 3, p. 277-290, 2009.