International Journal on Advanced Science Engineering Information Technology

Vol.12 (2022) No. 6
ISSN: 2088-5334

Study of Nisi Chicken Diversity Based on Morphometric Analysis and Bioacoustics Analysis

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***Abstract*— This study aims to obtain data on the diversity of nisi chickens based on morphometric analysis of body weight and bioacoustics analysis of the crowing sound. The number of studies linking morphometric analysis with bioacoustics analysis is one of the reference sources used in this study. In the future, it is hoped that this research will be one of the knowledge contributions for further or similar research. The parameters used in the analysis are neck length for morphometric analysis and bioacoustics parameters using the number of crowing syllables, crowing duration, and wave frequency. The data generated from the morphometric analysis were then analyzed statistically for the average test using ANOVA, which was analyzed together with the data generated from the Cold Edit Pro software to conclude the resulting data. The parameters observed were the number of crowed syllables, crowing duration, wave frequency, and crowing frequency. The results showed that the duration of the crowing of the nisi chicken ranged from 1.922 seconds to -2.064 seconds, with an average duration of 1.9837 seconds. The morphometric analysis of neck length results showed that the average neck length of 30 chicken samples was 10.25 cm, with the shortest range being 10.0 cm and the longest being 10.8 cm. The sound analysis results for the wavelength frequency of the crowing of the nisi chicken ranged from 698.10 Hz - 786.22 Hz with an average wavelength of 733.89 Hz. For the number of syllables produced from the crowing sound, uniform results are obtained in 7 syllables. The analysis results using ANOVA obtained an F count of 0.001447, smaller than F table 1.656383. This study concludes that the neck length morphometric analysis does not affect the bioacoustics analysis, so the diversity of nisi chickens analyzed shows uniformity**.

***Keywords*— Rooster; bioacoustics; frequency; cold edit pro; morphometric.**

Manuscript received 21 Jul. 2021; revised 9 Sep. 2021; accepted 13 Jan. 2022. Date of publication 31 Dec. 2022.

I. INTRODUCTION

Nisi chicken (*maluo diti*) is a native Gorontalo chicken scattered in residential areas around the mountains, which is starting to be difficult to get. This type of chicken is a native of Gorontalo, which has a potential genetic resource value if further studies are carried out. The general community uses chicken for several economic, social, and cultural aspects. [1]–[4]. Several studies on the nisi chicken as a genetic resource continue to be carried out to dig up information about the existence of this chicken species so that it becomes a new genetic resource known to the public regarding the study information. Some studies on diversity in chickens generally use genetic markers [5]–[12] and morphometric [3], [13]–[15], but this study uses bioacoustics and morphometric characters to see the correlation of these two parameters to diversity. According to [16], For some Indonesian people, chicken not only has economic value but can also have cultural value. The study of nisi chicken is considered very necessary considering that nisi chicken is a genetic resource that has not been explored so information about this type of chicken is quite limited. The scientific literature on this species has also never been written for publication, so this study has excellent novelty potential for research. [17] conducted research on bioacoustics analysis that correlated the morphometric analysis of local chickens on singer chickens, which included laughing chickens of dangdut and slow types, *balenggek kokok* chickens, *pelung* chickens, and *bekisar* chickens [15], [16], [18]–[21]. Similar to this, Zulistiana and Abinawanto [20] conducted a morphometric study that was connected with bioacoustics analysis to conduct diversity studies on laughing chickens. Bioacoustics analysis was carried out to describe the diversity of nisi chickens based on the resulting crow sound pattern. A rooster crowing is a natural behavior, carried out for several reasons, including to warn his opponent about his territory and this trait will be more aggressive if another male is also present in his territory by crowing [17].

The sound of crowing in chickens is one of the characteristics that function as a call and a song. Because this character then makes chickens can be grouped based on the uniqueness of their crows, people will recognize singer chickens, namely chickens with a unique crow sound, such as laughing chickens, *pelung* chickens, *balenggek* crows, *bekisar* chickens, *gaok* chickens and so on. Meanwhile, the father, who has the usual crowing sound, is not grouped into the type of singer chicken [18], [22]–[26].

The sound of crowing in chickens will vary between individuals, and this difference can be caused by internal factors (genetic) and external factors (nutrients and environment). Therefore, this study will raise the theme of nisi chicken diversity based on bioacoustics and morphometric analysis. The limited information regarding the study of nisi chicken makes this research have a very good conservation value because the success in conducting this study will open up opportunities to add new information about local Indonesian chicken species. Based on this background, this research was conducted with the hope that in the future, this research is expected to be one of the contributions of science for further research or similar research. In addition, with this research, it is hoped that Nisi Chicken, a local chicken from Gorontalo, can be one of the genetic resource assets that can be preserved.

II. Materials and Methods

A. Materials

This research was conducted in Gorontalo Province, which is located in Pinogu Village, Bone Bolango Regency. The sample used is a male nisi chicken that can crow. Sample selection was carried out with the criteria that the adult rooster's feet had grown horns of at least 0.5-1 cm. This is done to ensure that the chickens used are sexually mature so that the crow produced is the crowing sound of an adult chicken.

B. *Parameters* analyzed.

The parameters used in conducting the analysis were neck length for morphometric analysis, while for bioacoustics analysis, the number of crowing syllables, crowing duration, and wave frequency was used. Analysis of the number of syllables is seen based on the number of sound waves formed from the sound analysis. The number of sound waves will be assumed to be the number of syllables. The analysis of the crowing duration is based on the length of time the crowing occurs, which is calculated using the unit of time (seconds). Wave frequency analysis is the crowing wave path produced by the crowing sound.

C. Data Analysis

For the morphometric parameters, an analysis of the average ANOVA test was carried out to see if there was a morphometric effect of neck length on the resulting bioacoustics variation, while for the bioacoustics parameters, it was done by recording the sound of the crowing and then analyzed using Cold Edit Pro software version 2.1. The data generated from this software is then processed using descriptive statistical analysis through an average test to conclude the data generated.

III. Results and Discussion

A. Morphometric and Bioacoustics Data

The bioacoustics analysis results are shown in (Table 1). The table shows that the average number of crowing durations resulting from the measurement of the crowing time of 30 male nisi chickens obtained an average value of 1.9837 seconds. As for the wave frequency, the average frequency value is 733.89 Hz. For morphometric analysis, the results for neck length are in the range of 10.0 – 10.8, with an average of 10.25.

TABLE I
THE RESULTS OF MORPHOMETRIC ANALYSIS OF NECK LENGTH AND BIOACOUSTICS SOUND OF NISI CHICKEN CROW

Sample	Bioacoustics Parameters			Morphometric Parameters
	Number of Syllables	Crow Duration (Second)	Wave Frequency (Hz)	Neck Length (cm)
1	7	2.064	786.22	10.8
2	7	1.922	722.24	10.0
3	7	1.936	716.12	10.2
4	7	1.998	711.26	10.5
5	7	1.931	706.10	10.7
6	7	2.022	755.20	10.6
7	7	2.010	716.22	10.1
8	7	2.050	766.12	10.6
9	7	1.999	752.20	10.5
10	7	1.981	773.12	10.1
11	7	1.992	699.12	10.2
12	7	2.010	698.10	10.4
13	7	1.993	712.21	10.3
14	7	1.999	715.22	10.5
15	7	1.998	732.22	10.3
16	7	1.934	726.10	10.3
17	7	1.966	782.24	10.3
18	7	1.982	780.12	10.2
19	7	1.988	775.24	10.2
20	7	1.993	761.32	10.3
21	7	1.959	702.12	10.1
22	7	1.955	712.10	10.0
23	7	1.963	710.22	10.0
24	7	1.988	705.12	10.1
25	7	1.985	712.10	10.1
26	7	1.977	735.12	10.0
27	7	1.978	738.80	10.0
28	7	1.972	742.55	10.0
29	7	1.989	746.52	10.0
30	7	1.976	725.26	10.0
Average	7	1.9837	733.89	10.25

From the above data, a statistical analysis of the ANOVA test was carried out to see the relationship between neck length morphometric parameters and bioacoustics parameters, including the number of syllables, the duration of the crowing, and the frequency of the crowing sound waves.

B. Neck Length Morphometric Analysis

The neck length morphometric analysis results, as shown in (Fig. 1) show that the neck length is in the range between 10.0 cm – 10.8 cm. From these results, it can be seen that there are variations in several neck length measurements, which will then be statistically analyzed to see their effect on the results of the bioacoustics analysis.

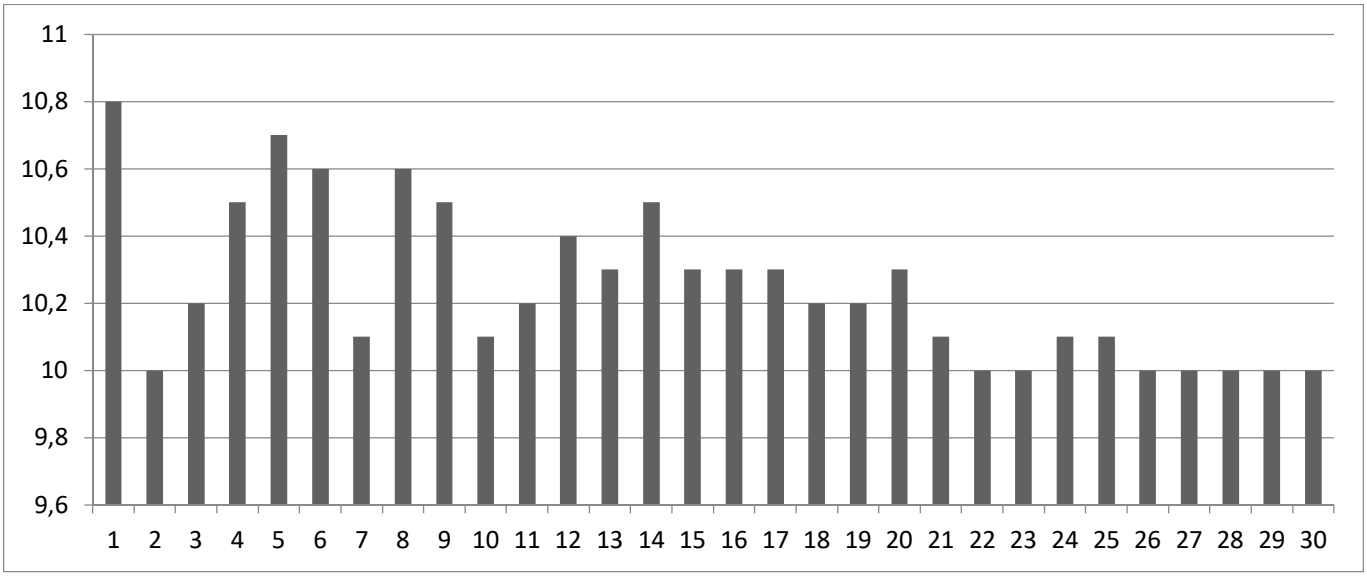

Fig. 1 Neck length morphometric analysis

C. Wave frequency analysis

The results of the wavelength-frequency analysis, as shown in (Fig. 2) show the range of crowing duration between 698.10 Hz – 786.22 Hz. From the figure, it can also be seen that sample numbers 10 and 11 have wavelengths below 700 Hz, 11 samples are below 720 Hz, and 17 samples have wavelengths above 720 Hz. These results indicate that there are several frequency classes obtained by bioacoustics analysis of the frequency of the crowing sound waves

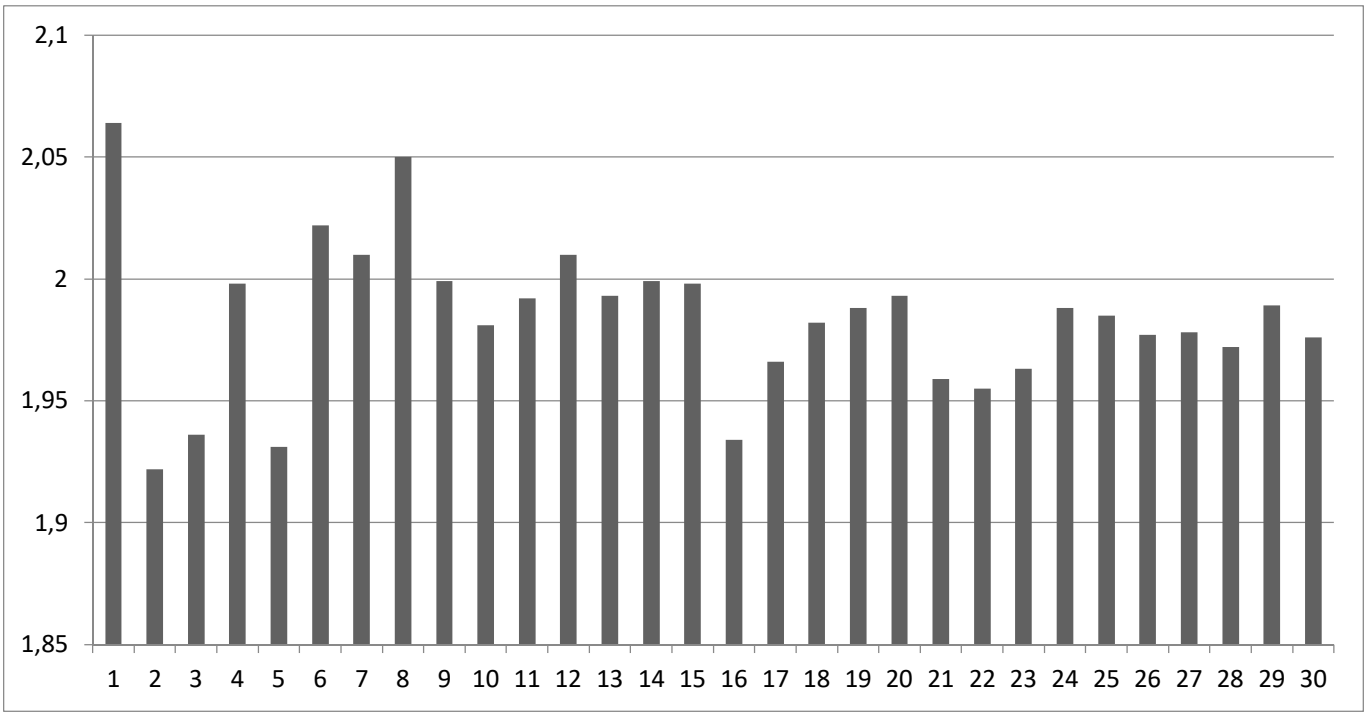

Fig. 2 Wave frequency analysis bar chart

D. Crow Duration Analysis

The results of the analysis of the crowing duration, as shown in (Fig. 3) show the range of crowing duration between 1.922 seconds and 2.064 seconds. The duration of this crowing is measured from the first time the rooster begins to crow until the last sound it makes. Based on the analysis of the crowing duration, as shown in the figure below, it is known that four chickens have a crowing duration below 1.95 seconds and 26 chickens above 1.95 seconds.

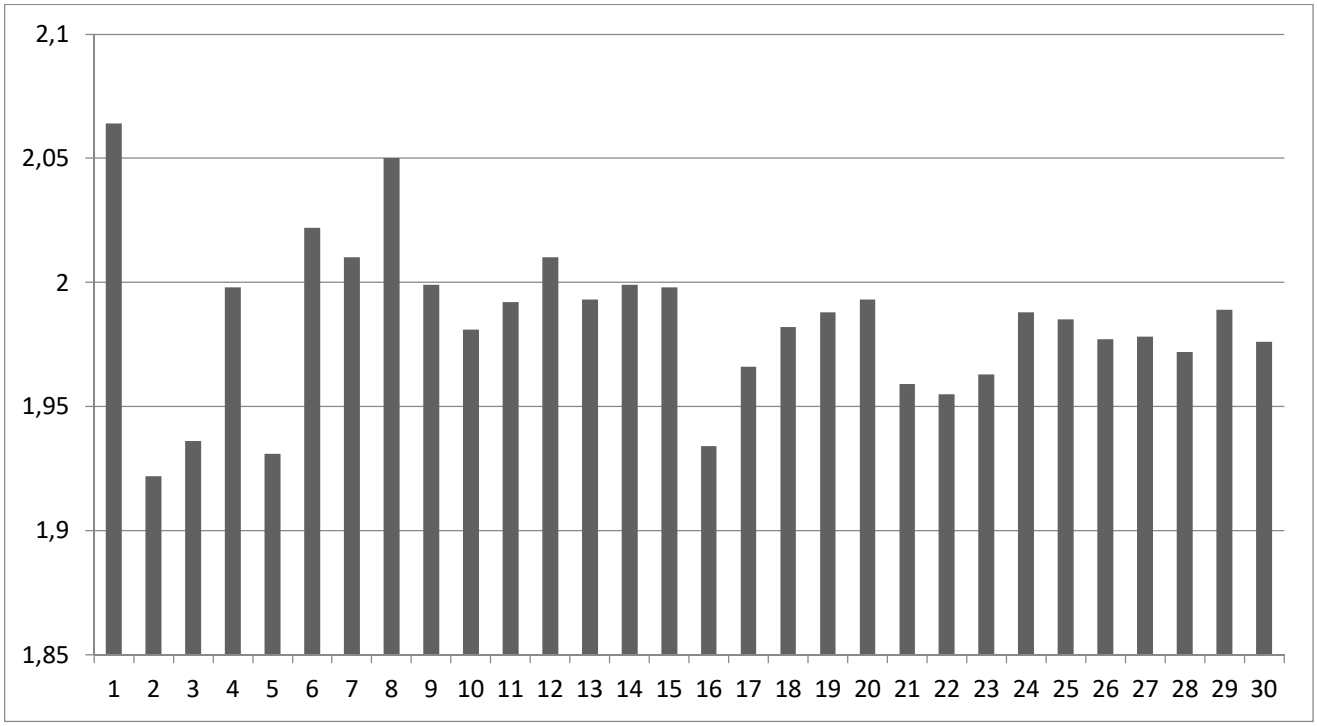

Fig. 3 Crow duration analysis bar chart

E. Bioacoustics Software Result

The results of the analysis of the frequency of the crow sound using the Cold Edut Pro software version 2.1 can be seen in Figure 4. In the picture, it can be seen visually that a crowing looks the same. Therefore in this data, only some data are shown, which are considered to represent other data.

The resulting data, as shown in the visual, shows different patterns. When viewed carefully and thoroughly, this difference shows that this pattern correlates with the frequency of the sound wave and the duration of the crowing sound. Therefore, it is important to conduct this research to provide new information and data regarding the crowing pattern of the nisi chicken, which is one of Indonesia's original genetic resources that has not yet been explored for its crowing pattern.

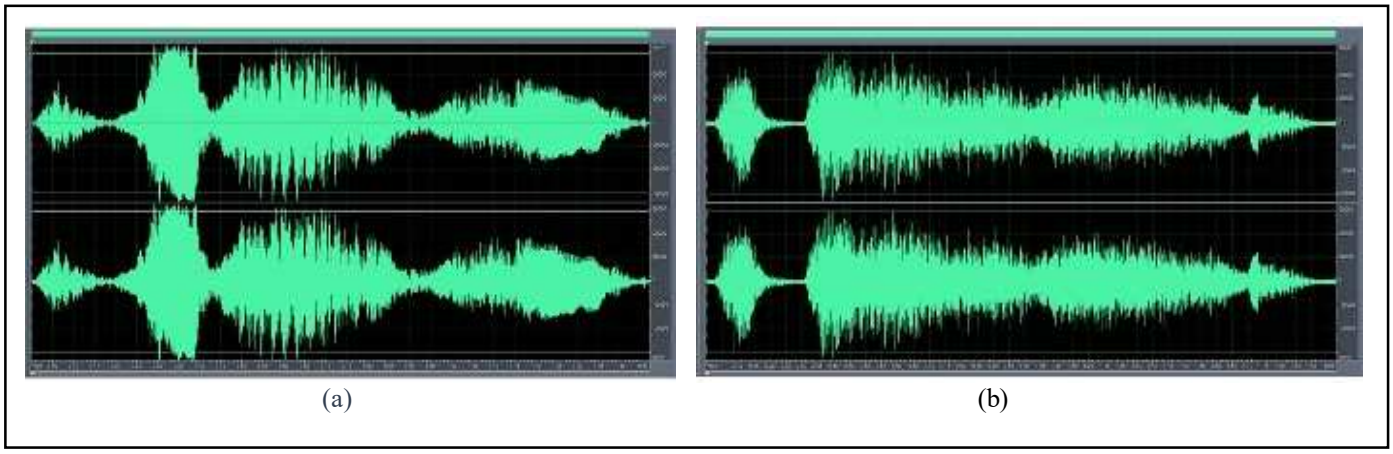

Fig. 4 The results of the bioacoustics analysis of four types of male Nisi chicken crow sounds.

F. Discussion

Neck length morphometric analysis was carried out to see the relationship between bioacoustics analysis in seeing the diversity of nisi chicken species. Research on morphometric and bioacoustics has been carried out by several researchers, such as Abinawanto and Effendi [19], in their research using morphometric and bioacoustics analysis to distinguish the type of dangdut laughing chicken and the slow type. From this study, it was also known that the morphometric length of the neck bone affects the duration of crowing in laughing chickens. However, in this study, different results were obtained from several studies conducted where in this study, after an ANOVA analysis was carried out on the morphometric parameters that were correlated with the bioacoustics parameters, the F count 0.001447 was smaller than F table 1.656383, which means that there is no effect on neck length to the cocoon produced. The morphometric analysis carried out on local chickens in Gorontalo showed a diversity of local chickens based on morphometric analysis

[3]. However, the nisi chicken is a different kind of chicken, and this type of chicken is a species that has not been studied. Therefore, this research is an important thing that can be done to provide information about the diversity of nisi chickens.

Bioacoustics is an applied science field that studies the characteristics of sound, sound-producing organs, sound function, sound physiology, sound analysis, and the benefits of animal and human sounds [18]. Another opinion was expressed by Mcloughlin, Stewart, and McElligott [27], which state that bioacoustics is the study of the acoustic characteristics and significance of sounds produced by living things. In most bird species, song sounds are only produced in male livestock. Therefore, a bioacoustics analysis was carried out on the crowing sound of roosters. The crowing sound in roosters is caused by steroid hormone activity and metabolic processes, which are secondary sex characteristics. According to Arlina et al. [18], sound production in chickens is caused by sexual dimorphism in the brain area. Control of singing in crowing is influenced by testosterone levels in the body [21]. Abinawanto et al. [15] also stated that the transmitted crow structure is influenced by steroid hormones, especially testosterone and estradiol. The vocal cords produce sound with the syrinx as the main sound-producing organ [19].

According to Abinawanto et al. [15], the hormone testosterone is one of the hormones that affects the crow of roosters. Chickens that enter adulthood will have a more stable testosterone hormone than those in their teens. This is what causes adult chickens to crow more often when compared to juvenile chickens. In addition to hormonal factors, crowing in chickens is also influenced by the shape and size of the vocal cord organs. According to Abinawanto and Effendi [19], the shape and size of the trachea, bronchi, and syringeal muscle mass can affect the vocal sounds released by songbirds. There are at least two types of voice functions in poultry: call and song. The chickens use the call sound to communicate and as a sign of danger, while the song sound is a type of sound as a statement of territory (territorial declaration) and as an attraction to attract female birds to be bred. The call sound type is found in male and female birds, while the song type is only found in male birds. Several software can be used to perform bioacoustics analysis, including Ashampoo Music Studio 6 software [20].

The varying duration of crowing can be influenced by several phenotype factors, namely vocal cord morphometrics or chicken body weight morphometrics used as samples. Abinawanto has carried out the effect of vocal cord morphometrics on crowing, and Effendi [19] stated that the morphometric size of the vocal cords could influence the length of the crowing sound or the duration of crowing. Research conducted by Asmara, Garnida, and Partasasmita [23], on *pelung* chickens correlated the age of *pelung* chickens with the duration of crowing, and the results were not significantly different. However, in further explanation of his research, it is known that the body weight and maturity of the sound-producing organs in chickens affect the duration of the crowing produced. Therefore, in this study, the sample used was determined by several basic criteria to select the maturity level of the sound-producing organs so that the sample used was an adult rooster, as evidenced by a minimum leg horn size of 0.5-1 cm. However, according to Daryono, Mushlih, and Perdamaian [28], the duration of the crow in chickens is influenced by a combination of internal factors (genetic) and external factors (nutrition and environment). This is in line with the research conducted by Osman, Yonezawa, and Nishibori [5] on laughing chickens. It was found that morphometric effects on the bioacoustics variation of the crowing sound produced.

The analysis of the frequency of the crowing sound waves can describe the variation of the crowing sound produced. The difference in the length of this frequency can vary between individuals. Several factors, including morphometric variations in the vocal cord organs, can cause this variation. This has been done in a study that correlates voice variation with vocal cord morphometrics by Zulistiana and Abinawanto [20], that vocal cord morphometrics affects the sound frequency of the crowing. Considering the number of syllables in the crow of the nisi chicken in all the test samples, it can be found that the same number of syllables was obtained after a bioacoustics analysis of 7 syllables.

Analysis of the diversity of chicken species, in general, has been carried out using molecule analysis using mitochondrial DNA genes [1], [5]–[8], [11], [12], [29]–[31]]. In addition, many morphometric analyzes have been carried out on local chickens and have shown good results for conducting diversity studies [1], [2], [6], [7]. Bioacoustics analysis is an analytical technique that uses sound patterns released by singing animals that have specific characteristics and patterns. This specificity is then used to conduct a kinship analysis. Research on the use of this bioacoustics technique has been widely carried out by some previous studies [5]–[11], [20], [21] and has been applied in biological research on species diversity [26]. Therefore, this research will be very useful in conducting studies on indigenous local chicken species whose existence information needs to be known so that they can be appointed as one of the genetic resources which are one element of the biological wealth of a nation.

IV Conclusion

As a conclusion in this study, the results of the bioacoustics analysis carried out on nisi chickens show that nisi chicken is not a singer chicken where the average range of crowing duration is shorter when compared to singer chickens or other local chickens. However, this opens a new knowledge about the character of nisi chicken where this bioacoustics analysis can map the diversity of nisi chicken when compared to other local chickens

Acknowledgment

The authors would like to thank the Kementerian Riset dan Teknologi/Badan Riset dan Inovasi Nasional for the financial support through the PDUPT with contract no. NKB-2793/UN2.RST/HKP.05.00/2020.

References

[1] A. Sophian and Abinawanto, "Study of Co1 and BIK BCL2 Gene Analysis in Gorontalo Local Chicken," *J. Hunan Univ. Nat. Sci.*, vol. 49, no. 1, pp. 220–227, 2022, doi: 10.55463/issn.1674-2974.49.1.28.

[2] A. Sophian, "Gorontalo Local Chicken Diversity Based on IGF-1 (Insulin-Like Growth Factor 1) Gene Analysis," 2021.

[3] A. Sophian, Abinawanto, U. C. Nisa, and Fadhillah, "Morphometric analysis of Gorontalo (Indonesia) native chickens from six different regions," *Biodiversitas*, vol. 22, no. 4, pp. 1757–1763, 2021, doi:

10.13057/biodiv/d220420.
[4] A. Sophian and A. Abinawanto, "Diversity of Nerve Growth Factor and Progesterone Receptor Genes in Nisi Chicken 2 . Materials And Methods," vol. 48, no. 10, 2021.
[5] S. A. M. Osman, T. Yonezawa, and M. Nishibori, "Origin and genetic diversity of Egyptian native chickens based on complete sequence of mitochondrial DNA D-loop region," *Poult. Sci.*, vol. 95, no. 6, pp. 1248–1256, 2016, doi: 10.3382/ps/pew029.
[6] H. Meydan, C. P. Jang, M. A. Yildiz, and S. Weigend, "Maternal origin of Turkish and Iranian native chickens inferred from mitochondrial DNA D-loop sequences," *Asian-Australasian J. Anim. Sci.*, vol. 29, no. 11, pp. 1547–1554, 2016, doi: 10.5713/ajas.15.1060.
[7] P. Teinlek, K. Siripattarapravat, and C. Tirawattanawanich, "Genetic diversity analysis of Thai indigenous chickens based on complete sequences of mitochondrial DNA D-loop region," *Asian-Australasian J. Anim. Sci.*, vol. 31, no. 6, pp. 804–811, 2018, doi: 10.5713/ajas.17.0611.
[8] A. Hata *et al.*, "Geographic origin and genetic characteristics of japanese indigenous chickens inferred from mitochondrial d-loop region and microsatellite dna markers," *Animals*, vol. 10, no. 11, pp. 1–23, 2020, doi: 10.3390/ani10112074.
[9] N. Dorji, M. Duangjinda, and Y. Phasuk, "Genetic characterization of Bhutanese native chickens based on an analysis of Red Junglefowl (Gallus gallus gallus and Gallus gallus spadecieus), domestic Southeast Asian and commercial chicken lines (Gallus gallus domesticus)," *Genet. Mol. Biol.*, vol. 35, no. 3, pp. 603–609, 2012, doi: 10.1590/S1415-47572012005000039.
[10] C. J. P. Godinez, P. J. D. Dadios, D. M. Espina, M. Matsunaga, and M. Nishibori, "Population Genetic Structure and Contribution of Philippine Chickens to the Pacific Chicken Diversity Inferred From Mitochondrial DNA," *Front. Genet.*, vol. 12, no. July, pp. 1–13, 2021, doi: 10.3389/fgene.2021.698401.
[11] Q. Li *et al.*, "Genetic diversity and relationship of Dulong chickens using mitochondrial DNA control region," *Mitochondrial DNA Part B Resour.*, vol. 5, no. 1, pp. 275–280, 2020, doi: 10.1080/23802359.2019.1700837.
[12] L. Zhang *et al.*, "Genetic evidence from mitochondrial DNA corroborates the origin of Tibetan chickens," *PLoS One*, vol. 12, no. 2, pp. 1–11, 2017, doi: 10.1371/journal.pone.0172945.
[13] M. Petracci, F. Sirri, M. Mazzoni, and A. Meluzzi, "Comparison of breast muscle traits and meat quality characteristics in 2 commercial chicken hybrids," *Poult. Sci*., vol. 92, no. 9, pp. 2438–2447, 2013, doi: 10.3382/ps.2013-03087.
[14] "Morphology of Breast and Thigh Muscles of Red Jungle Fowl, Malaysian Village Chicken, and Commercial Broiler Chicken.Pdf." .
[15] Abinawanto, A. Sophian, P. Effendi, and T. Siswantining, "Short communication: Variation in vocal cord morphometric characters among dangdut type and the slow type gaga chicken," *Biodiversitas*, vol. 19, no. 5, pp. 1902–1905, 2018, doi: 10.13057/biodiv/d190542.
[16] Abinawanto, A. Sophian, R. Lestari, A. Bowolaksono, P. S. Efendi, and R. Afnan, "Analysis of IGF-1 gene in ayam ketawa (Gallus gallus domesticus) with dangdut and slow type vocal characteristics," *Biodiversitas*, vol. 20, no. 7, pp. 2004–2010, Jul. 2019, doi: 10.13057/biodiv/d200729.
[17] S. R. A. Bugiwati, M. I. A. Dagong, and T. Tokunaga, "Crowing characteristics of native singing chicken breeds in Indonesia," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 492, no. 1, 2020, doi: 10.1088/1755-1315/492/1/012100.
[18] F. Arlina, Rusfidra, D. Andriano, and C. Sumatri, "Short communication: The type and sound diversity of kukuak balenggek chicken (gallus gallus domesticus) reared in West Sumatra, Indonesia," *Biodiversitas*, vol. 21, no. 5, pp. 1914–1919, 2020, doi: 10.13057/biodiv/d210518.
[19] A. Abinawanto and P. S. Effendi, "The bioacoustics analysis and the morphometrics study of the gaga's chicken (Ayam Ketawa) from Pinrang and Kebayoran Lama," *AIP Conf. Proc.*, vol. 2023, no. 2018, 2018, doi: 10.1063/1.5064134.
[20] T. Zulistiana and A. Abinawanto, "Morphometric and bioacoustic analysis Gaga chicken (Gallus gallus domesticus) at Bangkalan, Kamal Madura," *AIP Conf. Proc.*, vol. 2023, no. October 2018, 2018, doi: 10.1063/1.5064139.
[21] B. S. Daryono, M. Mushlih, and A. B. I. Perdamaian, "Crowing sound and inbreeding coefficient analysis of Pelung chicken (Gallus Gallus domesticus)," *Biodiversitas*, vol. 22, no. 5, pp. 2451–2457, 2021, doi: 10.13057/biodiv/d220501.
[22] W. Penar, A. Magiera, and C. Klocek, "Applications of bioacoustics in animal ecology," *Ecol. Complex.*, vol. 43, no. June, 2020, doi: 10.1016/j.ecocom.2020.100847.
[23] I. Y. Asmara, D. Garnida, and R. Partasasmita, "Crowing characteristics of Pelung chickens at different age and body weight," *Biodiversitas*, vol. 21, no. 9, pp. 4339–4344, 2020, doi: 10.13057/biodiv/d210953.
[24] I. Y. Asmara, D. Garnida, and R. Partasasmita, "Short communication: Duration and volume of crowing of pelung chickens of West Java, Indonesia," *Biodiversitas*, vol. 21, no. 2, pp. 748–752, 2020, doi: 10.13057/biodiv/d210242.
[25] T. Kuwayama, H. Ogawa, I. Munechika, T. Kono, and K. Ichinoe, "Crowing Characteristics of Jungle Fowls, Japanese Native Breeds and White Leghorn Breed of Chicken.," *Japanese Poult. Sci.*, vol. 33, no. 2, pp. 89–95, 1996, doi: 10.2141/jpsa.33.89.
[26] M. Calviño-Cancela, L. Piña, and J. Martín-Herrero, "Bioacoustic differentiation of calls in the chiffchaff complex," *PeerJ*, vol. 10, pp. 1–22, 2022, doi: 10.7717/peerj.14261.
[27] M. P. Mcloughlin, R. Stewart, and A. G. McElligott, "Automated bioacoustics: Methods in ecology and conservation and their potential for animal welfare monitoring," *J. R. Soc. Interface*, vol. 16, no. 155, 2019, doi: 10.1098/rsif.2019.0225.
[28] B. S. Daryono, M. Mushlih, and A. B. I. Perdamaian, "Vocalizaon characters and forkhead box p2 (foxp2) polymorphism in Indonesian crowing-type chicken (Gallus gallus domesticus)," *Iran. J. Appl. Anim. Sci.*, vol. 10, no. 1, pp. 131–140, 2020.
[29] O. N. Okumu *et al.*, "Genetic diversity of indigenous chickens from selected areas in Kenya using microsatellite markers," *J. Genet. Eng. Biotechnol.*, vol. 15, no. 2, pp. 489–495, 2017, doi: 10.1016/j.jgeb.2017.04.007.
[30] S. Phromnoi, P. Lertwatcharasarakul, and S. Phattanakunanan, "Genetic diversity and phylogenetic analysis of Khiew-Phalee chickens (Thailand) based on mitochondrial DNA cytochrome b gene sequences," *Biodiversitas*, vol. 23, no. 2, pp. 750–756, 2022, doi: 10.13057/biodiv/d230220.
[31] M. B. Herrera *et al.*, "East African origins for Madagascan chickens as indicated by mitochondrial DNA," *R. Soc. Open Sci.*, vol. 4, no. 3, 2017, doi: 10.1098/rsos.160787.