DETERMINING THE INITIAL TIME OF MORNING PRAYER USING THE SOUND OF A ROCK'S CROWD

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Abstract

Fajr al-ṣādiq is an indication of the entry of *Fajr* time. Another indication is the sound of a rooster's crowing, which can be predicted based on his biological clock. Apart from that, roosters also have eyes that are sensitive to light, so the rooster crows very loudly in the morning. This research tries to find out what the astronomical conditions are like when roosters start crowing. This research was carried out by direct observation in the field to obtain accurate results. The results of this research are that the sound of a rooster's crowing can be used as an alarm for dawn but cannot be used as a definite reference for the start of dawn because the roosters are busy crowing several moments after dawn.

***Keywords**: Dawn, Rock's Crowd, Payer Time*

Abstrak

Fajr al-ṣādiq menjadi salah satu indikasi masuknya waktu Subuh. Salah satu indikasi lainnya adalah sounds kokok ayam jantan yang dapat diprediksi waktunya berdasarkan jam biologisnya. Selain itu, ayam jantan juga memiliki mata yang peka terhadap cahaya sehingga di pagi hari ayam jantan berkokok dengan sangat nyaring. Penelitian ini mencoba untuk mengatahui bagaimana kondisi astronomis ketika ayam jantan mulai ramai berkokok. Penelitian ini dilakukan dengan observasi langsung di lapangan agar diperoleh hasil yang akurat. Hasil dari penelitian ini adalah sounds kokok ayam jantan dapat digunakan sebagai alarm terbitnya fajar namun belum dapat dijadikan sebagai acuan pasti awal masuknya waktu shubuh karena ayam jantan ramai berkokok bersautan beberapa saat setelah fajar terbit.

***Keywords:** Fajar, Kokok Ayam Jantan, Waktu Salat*

A. Introduction

The beginning of dawn is marked by the rising of *ṣādiq* dawn on the eastern horizon.[1] *Fajr Ṣādiq*, also known as astronomical twilight, the light that appears before the Sun rises, is rather bright white and spreads across the eastern horizon. Some believe that dawn increases when the Sun's height is around 18º below the horizon. However, another opinion says that the shadow dawn rises when the Sun is 20º below the horizon.[2] In Indonesia, a country with various types of chickens, you are undoubtedly familiar with the sound of roosters crowing every morning. Even ancient rural people used the crowing of a rooster in the morning as a sign that the Sun would soon rise. According to research, roosters can capture ultraviolet light well because they have seven photoreceptor cells in their eyes.[3] Another discovery also suggests that roosters have a unique ability, namely that there is a biological clock in their bodies, and the loudest crowing sound occurs when dawn comes.[4]

In an authentic hadith narrated by Abū Dāwud, it is stated "*From Zayd Ibn Khālid Al-Juhany ra. said, the Messenger of Allah said: "Don't curse the rooster because in fact the rooster can wake up the prayer" (HR Abu Daud).'*'[5] This hadith further confirms that the crowing of a rooster in the morning signals the arrival of dawn. Early people in Indonesia also used the rooster's crowing to signal the morning's arrival. So, in this research, we want to discuss further how the sound of a rooster's crowing correlates with the dawn time as a dawn marker.

There are many studies related to determining the beginning of the dawn prayer time that have been published in various scientific journals and conferences.

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[1] Ahmad Izzuddin, *Ilmu Falak Praktis* (Semarang: Pustaka Rizki Putra, 2012); Muhyiddin Khazin, *Ilmu Falak Dalam Teori Dan Praktik* (Yogyakarta: Buana Pustaka, 2004); Susiknan Azhari, *Ilmu Falak: Perjumpaan Khazanah Islam Dan Sains Modern*, 2nd ed. (Yogyakarta: Sounds Muhammadiyah, 2007); Slamet Hambali, *Ilmu Falak I (Penentuan Awal Waktu Shalat &Arah Kiblat Seluruh Dunia)* (Semarang: Program Pascasarjana IAIN Walisongo, 2011).

[2] Hambali, *Ilmu Falak I (Penentuan Awal Waktu Shalat &Arah Kiblat Seluruh Dunia)*.

[3] Yoseph A. Kram, Stephanie Mantey, and Joseph C. Corbo, "Avian Cone Photoreceptors Tile the Retina as Five Independent, Self-Organizing Mosaics," *PLoS ONE* 5, no. 2 (February 1, 2010), https://doi.org/10.1371/journal.pone.0008992.

[4] Tsuyoshi Shimmura, Shosei Ohashi, and Takashi Yoshimura, "The Highest-Ranking Rooster Has Priority to Announce the Break of Dawn," *Scientific Reports* 5 (July 23, 2015), https://doi.org/10.1038/srep11683.

[5] Abu Daud, *Sunan Abi Daud*, 3rd ed. (Beirut: Dar al-Kutub al-Ilmiyyah, 1996).

Some of them are research conducted by Hendro Setyanto,[6] Muhammad Basthoni, Ahmad Izzuddin,[7] Ismail Fahmi[8] and several other experts. However, from several studies, none have specifically discussed the crowing of roosters as a method in determining the time of dawn prayers. The purpose of this study is to determine the astronomical conditions when roosters start crowing, and also to determine whether roosters can be used as a natural alarm for the entry of dawn prayer time. This study is expected to be a means for the author to study how the correlation between roosters crowing sounds and the beginning of dawn prayer time, and can add to the scientific treasury in the field of astronomy so that it can be used as a reference by other researchers.

B. Method

The research method used in this research is quantitative, with a field research approach where the data is obtained directly from facts in the field. This research uses two data sources, namely primary data sources from the researcher's observations. Meanwhile, secondary data consists of related articles, journals, and books. The data collection techniques used are observation and documentation. Observations were carried out in Banyutowo Village, Pati Regency, using 14 roosters aged seven months - 1.5 years as samples of rooster crowing sounds while measuring astronomical conditions using a LU DL type SQM installed facing the eastern horizon on the coast. The documentation method used by researchers is utilizing journals, articles, books, and encyclopedias related to this research.

[6] Hendro Setyanto and Muhammad Basthoni, "Analisis Tipologi Kurva Cahaya Senja-Fajar," in *Peran Ilmu Falak Dalam Menghadapi Revolusi Industri 4.0*, 2020; Hendro Setyanto et al., "Zodiac Light Detection Based on Sky Quality (Sqm) Data: Preliminary Study," *Al-Hilal: Journal of Islamic Astronomy* 3, no. 1 (May 2021): 121–34, https://doi.org/10.1086/676819.

[7] Ahmad Izzuddin and M Basthoni, "Using Command-Line and Graphical User Interfaces Program in Determining Dawn in Pollutive and Non-Pollutive Area," *Webology* 19, no. 1 (2022): 5879–92, http://www.webology.org.

[8] Ismail Fahmi et al., "Zodiacal Light and Astronomical Twilight Measurement at Timau Nasional Observatory Site," in *AIP Conference Proceedings*, vol. 3074 (American Institute of Physics, 2024), 1–7, https://doi.org/10.1063/5.0211329.

C. Results and Discussion

C.1. *Fajr Ṣādiq*

Fajr ṣādiq is taken from Arabic, which means actual, the real situation. Meanwhile, in terms of *ṣādiq* dawn, it is defined as the real dawn in the form of light that stretches across the eastern horizon horizontally, which is caused by scattering by the Earth's atmosphere. There is no darkness after this dawn rises. Visually, this dawn is orange (golden), beginning with a few white streaks, sometimes reddish and sometimes orange. This dawn is the time limit for night and day, with a period of approximately 1 hour above the equator.[9] Experts, through the results of their ijtihad, have different criteria for the height of the Sun at dawn *ṣādiq*. The following are the criteria for the height of the Sun for each expert:

Table 1: *Fajr ṣādiq* from Expertise

Expertise/Institution	Sun Altitude
Almanak Nautika	18º
Abu Raihan al-Biruni	15º-18º
Kementrian Agama	20º
Zubair Umar al-Jailany	18º
Muhammad Thahir Jalaluddin	20º
Muhammad Ilyas, Muhammad al-Mu'thy Maryn ar-Ribathy, Ali bin Abdul Qadir al-Buntity al-Hanafy, Muhammad bin Muhammad bin Ibrahim al-'Alamy, Ibn ar-Raqqam, Abd. ar-Rahman at-Tajury al-Ifriqy, Muhammad Yasin bin Isa Padang, Muhammad Shalih bin Harun Kamboja, Teuku Muhammad Ali Irsyad	19º

The following are the criteria for the height of the Sun at dawn according to international organizations, including:

Table 2. Sun Altitude Criteria According to International Organizations

Organization	Sun Altitude	Countries
University of Islamic Science of Karachi	18º	Pakistan, Bangladesh, India, Afganistan, dan Eropa
Islamic Society of North America (ISNA)	15º	Canada, Amerika
Muslim World League	18º	Eropa, Amerika Serikat
Ummul Qurra Committee	19,5º	Arabian Peninsula
Institute of Geophysics, University of Tehran	17,7º	Iran
Shia Ithna Ashari, Leva Research Institute, Qum	16º	Iran

[9] AR Sugeng Riyadi, "Menalar Waktu Subuh," in Mempertanyakan Temuan Waktu Sholat Isya Dan Subuh Baru (Semarang: Universitas Islam Negeri, 2018). 6.

C.2. Eye Structure and Rooster Crowing Sound

Roosters are animals belonging to the class Aves or birds, known to have very sharp eyesight compared to other vertebrate animals. Aves' sharp vision is due to the unique structure of their retina. The retinas of birds have very sophisticated photoreceptors, making them superior in visual abilities. Aves' retinas consist of five types of cone cells, each of which has a vital role in their vision. Four of these are single cone cells that support tetrachromatic color vision, allowing birds to see various colors very well. This is a crucial ability, especially regarding navigation and finding food. They also have double cone cells mediating the perception of achromatic movement, namely the perception of movement without color. This ability enables birds to detect movement very accurately, which is vital for their survival in hunting prey and avoiding predators.[10]

Roosters are a type of bird commonly found in Indonesia and have unique characteristics compared to most other diurnal birds in this region. One of the unique characteristics of roosters lies in the very complex and distinctive structure of the retina of their eyes, which consists of seven types of photoreceptor cells, namely one-rod cells and six cone cells. These photoreceptor cells play an essential role in roosters' visual abilities, especially in color vision and light perception. Four of the six are single cones that function as mediators of tetrachromatic vision, allowing roosters to respond best to violet, blue, green, and red colors. Meanwhile, the two double-cone cells have a higher sensitivity to longer wavelengths of light, giving roosters the ability to detect light in a broader spectrum. Furthermore, this rod cell only has an essential role in dim light conditions because rod cells are more sensitive than cone cells. When the environment is dark, these rod cells take over the function of vision, allowing roosters to continue to see in low-light conditions.

[10] Kram, Mantey, and Corbo, "Avian Cone Photoreceptors Tile the Retina as Five Independent, Self-Organizing Mosaics." 1.

The lack of rod cells in chicken photoreceptor cells means they cannot see at night, and the large number of cone cells means chickens can respond to light better. Therefore, chickens are more sensitive to light. Roosters are also vertebrates with a distinctive "kukkuruyuk" sound, often heard when dawn arrives, as well as at certain other times. Brenowitz divides two types of rooster sounds, namely call and song. The call sound is used to communicate between people, when finding food, and as a signal if there are enemies. Different from the song type, the singing sound is used to declare territory and is also used to attract hens who want to mate.[11] The sound of this song is usually heard in the morning, afternoon, evening, and night. However, among these times, the best song sounds are listened to in the morning.[12]

Rusfidra stated that roosters can crow for the most extended duration in the morning. This makes the morning the peak of rooster crowing activity, where the crowing sound is most often heard.[13] This statement was reinforced by Tsuyoshi Shimmura, who stated that the highest intensity of a rooster's crowing occurs just when dawn arrives. Shimmura supports this claim with research results showing that roosters consistently crow at dawn every morning as part of a response to their body's circadian clock. This circadian clock is an internal biological mechanism in the body of a rooster that regulates various physiological activities in a 24-hour cycle. This circadian clock regulates the timing of roosters' crowing and influences sleep, eating, and other activity patterns. In other words, the rooster's crowing at dawn is not a coincidence but rather the result of a precise synchronization between the external environment and the rooster's internal biological rhythm.

Specifically, Shimmura's research shows that even when ambient light conditions change, such as artificial light or differences in sunrise times,

[11] Rusfidra et al., "Identification of Bioacoustic Marker of Kokok Balenggek Song Fowl Inside A Captive Breeding Farm in 'Agutalok' Solok Regency, Indonesia," *Jurnal Peternakan Indonesia, Februar*y 14, no. 1 (2012): 303–7.

[12] Andika Verdian Ginting, Hamdan, and Tri Hesti Wahyuni, "Identifikasi dan Karakterisasi Pola Kokok Pada Ayam Pelihara Berdasarkan Pendekatan Bioakustik," *Jurnal Peternakan Integratif* 3, no. 2 (2015): 142–55.

[13] Rusfidra et al., "Identification of Bioacoustic Marker of Kokok Balenggek Song Fowl Inside a Captive Breeding Farm in 'Agutalok' Solok Regency, Indonesia."

roosters still crow at nearly the same time every day.[14] This suggests that roosters' morning crowing is driven more by their internal circadian clock than by external light. This is an example of how animals, including roosters, have highly regulated biological clocks, allowing them to adapt their behavior to natural cycles consistently. The rooster's crowing in the morning, often seen as a sign of the start of a new day, manifests the complexity and precision of his internal biological clock.

C.3. Correlation of the Sound of a Rooster's Crowing with the Start of Dawn

The research was conducted in Banyutowo Village, Pati Regency, and carried out for three days with the criteria of having more than ten roosters and the distance between residential areas and the coastline of approximately 500 meters. Apart from that, because the beach faces the eastern horizon and has astronomical conditions, there is still minimal light pollution because researchers use the Sky Quality Meter tool to monitor sky conditions. The research was conducted for 2 hours 10 minutes, from 03.10 to 05.20 WIB. This is based on obtaining data 1 hour before and 1 hour after. After determining the time for data collection, the author made sky observations using a Sky Quality Meter with the instrument facing the eastern horizon and recorded the sound of a rooster crowing. After all the data is collected, the data is processed in Microsoft Excel. Next, the data was compared with data obtained from www.timeanddate.com. Data on dawn time was taken from the Ministry of Religion, Central Jakarta. Finally, the data was analyzed so that conclusions could be drawn. The average data obtained:

[14] Shimmura, Ohashi, and Yoshimura, "The Highest-Ranking Rooster Has Priority to Announce the Break of Dawn."

Table 3: Crock Rooster Frequent on August 31

Time	Average Crock Rooster Frequent
03.10 - 03.32	2-3 sounds
03.33 - 03.35	25 sounds
03.36 - 03.51	3-4 sounds
03.52 - 04.00	12-13 sounds
04.01 - 04.11	7-8 sounds
04.12 - 04.17	15-16 sounds
04.18 - 04.31	5-6 sounds
04.32 - 04.48	9-10 sounds
04.49 - 05.20	13-14 sounds

Table 4: Crock Rooster Frequent on September 1

Time	Average Crock Rooster Frequent
03.10 - 03.26	1-2 sounds
03.26 - 03.33	19 sounds
03.34 - 04.03	4-5 sounds
04.04 - 04.22	13-14 sounds
04.23 - 04.32	9-10 sounds
04.33 - 05.20	15-16 sounds

Table 5: Crock Rooster Frequent on September 2

Time	Average Crock Rooster Frequent
03.10 - 03.15	20-21 sounds
03.16 - 03.25	2-3 sounds
03.26 - 03.30	8 sounds
03.31 - 03.39	2-3 sounds
03.40 - 03.52	16-17 sounds
03.53 - 04.08	4-5 sounds
04.09 - 04.21	12-13 sounds
04.22 - 04.32	4-5 sounds
04.33 - 05.20	14-15 sounds

From the table above, the crowing frequency of roosters shows quite significant fluctuations within 2 hours and 10 minutes. Although there are variations in the frequency of crowing, the pattern that emerges shows that roosters tend to crow simultaneously with a certain intensity 3-4 times each day. This pattern indicates a certain rhythm followed by roosters in crowing, which may be related to biological or environmental factors. Furthermore, based on the processed data, the mode of the average frequency of rooster crowing can be identified. This mode is the value that appears most often in the existing data, so it provides an idea of the specific times when rooster crowing is most often heard. Observing this mode can also provide further

insight into the growing habits of roosters under normal conditions and how this may be influenced by various external factors such as light, temperature, or social interactions with other roosters.

By knowing the average frequency and mode of rooster crowing, we can better understand this behavioral pattern, which is crucial not only for researchers in the field of ethology or the study of animal behavior but also for breeders who may want to optimize the environment for their chickens. The frequency and crowing pattern of roosters may indicate animal welfare, which may influence their productivity and overall health.

Table 6. Frequency Mode of Rooster Crow Sounds

Date	Time	Average
August 31	03.33 - 03.35	25 sounds
August 31	03.52 - 04.00	12-13 sounds
August 31	04.12 - 04.17	15-16 sounds
August 31	04.49 - 05.20	13-14 sounds
September 1	03.26 - 03.33	19 sounds
September 1	04.04 - 04.22	13-14 sounds
September 1	04.33 - 05.20	15-16 sounds
September 2	03.10 - 03.15	20-21 sounds
September 2	03.40 - 03.52	16-17 sounds
September 2	04.09 - 04.21	12-13 sounds
September 2	04.33 - 05.20	14-15 sounds

The table above shows that the high-frequency sounds of roosters crowing occur for a relatively short duration, namely around 5-20 minutes, at around 04.30. This pattern indicates that roosters begin to show crowing activity as soon as they sense changes in light or other environmental stimuli that signal the approach of dawn. This early crowing can be considered a natural "alarm" that signals that the day is about to begin. However, in contrast to this short crowing, there are other periods where the rooster's crowing sounds become louder and last longer. In the time range between 04.30 and 05.20, the frequency of crowing increased significantly, and the duration of this crowing ranged from 30 to 60 minutes. This phenomenon may be related to the brighter morning light, which triggers a sustained response from roosters to continue growing as part of their circadian behavior.

From the data obtained, the researchers concluded that the start time of the rooster's crowing, which indicates the rising of dawn, tends to be consistent, namely around 04.32 on August 31 and 04.33 on September 1 and 2. This very slight time difference indicates that roosters have a very regular rhythm in responding to changes in dawn time, which is strongly thought to be regulated by their internal circadian clock. This circadian clock governs the various daily activities of chickens, including the time they start crowing in the morning. Interestingly, the higher frequency of crowing and longer duration after 04:30 also indicates that roosters respond to dawn light and communicate with roosters. Others through crowing. This means complex social interactions between roosters, in which they signal their presence to each other and may also try to claim territory or demonstrate dominance. Heavy crowing at this time may serve as a mechanism to reinforce social hierarchy among roosters in a particular group or area.

After seeing the observation results above, I made observations with the Sky Quality Meter with the following results:

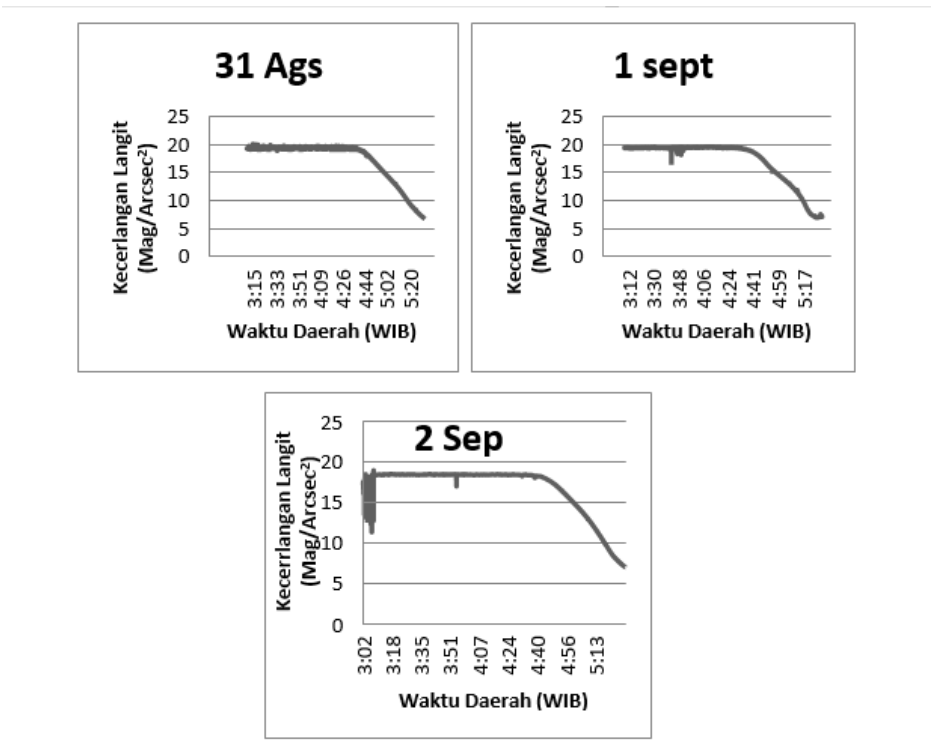

Figure 1. Sky Quality Meter Data

From the graph above, it can be seen that there is a steady decrease, which indicates changes in the intensity of light in the sky at a certain time. This decrease indicates that the darkness of the night is starting to decrease, marking the transition from night to morning gradually. This phenomenon is an important indicator in studying the time of dawn, especially dawn shades. Fajar Sadiq is a term used in Islamic tradition to signify the start of dawn, when light first appears on the eastern horizon, and the sky gradually brightens. This steady decline in the graph indicates that night darkness is not decreasing suddenly but slowly and consistently. In astronomy and natural observations, this steady decline is interpreted as a phase in which sunlight spreads into the atmosphere, even though the Sun is not yet visible above the horizon.

The process of dawn shade is closely related to an atmospheric phenomenon known as light scattering. When the Sun approaches the horizon, even though it is still below the horizon line, sunlight enters the Earth's atmosphere. Earth's atmosphere is made up of tiny particles that cause sunlight to scatter in all directions, a phenomenon known as Rayleigh scattering. This scattering causes the sky on the eastern horizon to brighten slowly. This graph shows decreasing darkness, which results from increased scattered light, which marks the beginning of dawn. By understanding this graph, we can conclude that a steady decrease in darkness is a reliable marker for predicting the appearance of the dawn of Sadiq. Sadiq dawn does not occur suddenly but through a smooth transition from night to morning, where the sky slowly changes from dark to light. Therefore, the steady decline in the graph can be used as an important indicator in determining the time of dawn with high accuracy.

This graph also provides insight into how atmospheric conditions affect our perception of dawn time. For example, in areas with high light pollution or thick clouds, the decline in darkness may be slower or less noticeable, affecting the observation of dawn shades. In contrast, these graphic dips may be more transparent and accessible in rural or mountainous areas, free from light pollution. In a broader context, graphic analysis is also helpful in studying atmospheric dynamics and climate change. The steady decline in darkness

reflects the interaction between sunlight and the Earth's atmosphere, which can be influenced by pollution, air composition, and weather conditions. By studying these patterns, scientists can gain deeper insight into how changes in the Earth's atmosphere affect our perception of natural phenomena such as dawn and how this may change over time.

Table 7. Sounds of roosters crowing when dawn *Ṣādiq* rises

Date	Time (SQM)	Rooster Crown
August 31	04.27	7 sounds
September 1	04.28	7 sounds
September 2	04.30	5 sounds

This data shows that when dawn begins to rise, according to measurements from the Sky Quality Meter (SQM), the frequency of rooster crowing sounds tends to be low. At this time, the roosters do not huddle together as is common at other times. This phenomenon indicates that as dawn begins to break, roosters may respond to changes in light in a quieter manner, reducing the intensity of their crowing. This could also indicate that this period is a transition where the roosters adjust from night to day, so their vocal activity is significantly reduced compared to the time before or after dawn.

The following is a combined result of the sound of a rooster crowing, astronomical conditions at the same time, dawn time according to the Ministry of Religion, and the difference:

Table 6. Data Combination

Date	Rooster Crown Time (A)	*Fajr ṣādiq* (SQM) (B)	Fajr Prayer Time (C)	Time Difference (A-B)	Time Difference (A-C)
August 31	04.32	04.27	04.19	5 minutes	13 minutes
September 1	04.33	04.28	04.18	5 minutes	15 minutes
September 2	04.33	04.30	04.18	3 minutes	15 minutes

Based on the results of the combined data obtained, it can be concluded that the sounds of rooster crowing with the highest frequency and long duration, namely around 30-60 minutes, occur around 3-5 minutes after dawn. This suggests that roosters increase their crowing activity as soon as dawn breaks. These crows last quite a long time and can be a strong indicator that the day has truly begun, according to their natural rhythm triggered by

changes in the intensity of morning light. Apart from that, there is a significant time difference between the Fajr call to prayer and the rooster's crowing time. This difference ranges from 13-15 minutes after the Fajr call to prayer is uttered. In this context, the Fajr call to prayer, which is a call to the Fajr prayer, is usually based on the time calculated astronomically related to the appearance of the dawn of *ṣādiq*. However, the data shows that roosters begin crowing intensively a few minutes after dawn as if they have a natural time signature slightly different from the calculated Fajr call to prayer.

Furthermore, the difference between the time of sunrise according to Sky Quality Meter (SQM) measurements and the time of the Fajr call to prayer is also quite striking, namely around 8-12 minutes. In this observation, the time of Fajr is determined to be earlier than the time of sunrise, as measured scientifically by SQM. This suggests that differences in methods for determining dawn time may result in variations in the resulting times. This earlier time for the Fajr call to prayer may be due to differences in approaches in determining when dawn begins, where astronomical calculations for worship can be more conservative or careful to ensure the time of worship starts on time. This time difference can provide deeper insight into how the natural rhythms of animals, in this case roosters, interact with scientifically and religiously established times. This phenomenon suggests that roosters may be more sensitive to natural environmental changes, such as increased light on the eastern horizon, than time calculations based on astronomical rules or tables.

In daily practice, understanding this time difference can be helpful for those who live in rural areas or rely on nature to mark prayer times. With their consistent crowing after dawn, Roosters may serve as a natural marker confirming dawn, which can then be compared with astronomically calculated times. This shows how vital direct observation of nature is, which remains relevant amidst increasingly sophisticated technological advances. Overall, these data provide an exciting picture of how natural phenomena such as rooster crowing can be synchronized with changes in natural light and how this compares with prayer times established based on astronomical

calculations. These observations could be interesting for further research, especially in understanding the relationship between animal biological rhythms and critical times in religious traditions.

D. Conclusion

Roosters have a unique retinal structure with seven photoreceptor cells, making them more light-sensitive than other vertebrates. Factors that influence a rooster's crowing include the circadian clock (internal factors) and external factors such as communication, finding food, danger signals, territory, attracting the attention of females, and sunrise. Research shows that the loudest rooster crowing occurs around 3-5 minutes after dawn, with the longest duration between 04.32-05.20 (August 31) and 04.33-05.20 (1-2 September). According to the data, dawn rises at 04.27-04.30, and rooster crowing can indicate dawn. However, it is only sometimes appropriate as a reference for the start of dawn due to sound fluctuations.

E. Bibliography

Azhari, Susiknan. *Ilmu Falak: Perjumpaan Khazanah Islam Dan Sains Modern*. 2nd ed. Yogyakarta: Sounds Muhammadiyah, 2007.

Daud, Abu. *Sunan Abi Daud*. 3rd ed. Beirut: Dar al-Kutub al-Ilmiyyah, 1996.

Fahmi, Ismail, Thomas Djamaluddin, Ahmad Izzuddin, M. Basthoni, Hendro Setyanto, Zam Zam Kusumaatmaja, and Ahmad Zulfi Aufar. "Zodiacal Light and Astronomical Twilight Measurement at Timau Nasional Observatory Site." In *AIP Conference Proceedings*, 3074:1–7. American Institute of Physics, 2024. https://doi.org/10.1063/5.0211329.

Ginting, Andika Verdian, Hamdan, and Tri Hesti Wahyuni. "Identifikasi dan Karakterisasi Pola Kokok Pada Ayam Pelihara Berdasarkan Pendekatan Bioakustik." *Jurnal Peternakan Integratif* 3, no. 2 (2015): 142–55.

Hambali, Slamet. *Ilmu Falak I (Penentuan Awal Waktu Shalat &Arah Kiblat Seluruh Dunia)*. Semarang: Program Pascasarjana IAIN Walisongo, 2011.

Izzuddin, Ahmad. *Ilmu Falak Praktis*. Semarang: Pustaka Rizki Putra, 2012.

Izzuddin, Ahmad, and M Basthoni. "Using Command-Line and Graphical User Interfaces Program in Determining Dawn in Pollutive and Non-Pollutive Area." *Webology* 19, no. 1 (2022): 5879–92. http://www.webology.org.

Khazin, Muhyiddin. *Ilmu Falak Dalam Teori Dan Praktik*. Yogyakarta: Buana Pustaka, 2004.

Kram, Yoseph A., Stephanie Mantey, and Joseph C. Corbo. "Avian Cone Photoreceptors Tile the Retina as Five Independent, Self-Organizing Mosaics." *PLoS ONE* 5, no. 2 (February 1, 2010). https://doi.org/10.1371/journal.pone.0008992.

Riyadi, AR Sugeng. "Menalar Waktu Subuh." In *Mempertanyakan Temuan Waktu Sholat Isya Dan Subuh Baru*. Semarang: Universitas Islam Negeri, 2018.

Rusfidra, YY Tumatra, MH Abbas, Y Heryandi, and F Arlina. "Identification of Bioacoustic Marker of Kokok Balenggek Song Fowl Inside A Captive Breeding Farm in 'Agutalok' Solok Regency, Indonesia." *Jurnal Peternakan Indonesia, Februari* 14, no. 1 (2012): 303–7.

Setyanto, Hendro, and Muhammad Basthoni. "Analisis Tipologi Kurva Cahaya Senja-Fajar." In *Peran Ilmu Falak Dalam Menghadapi Revolusi Industri 4.0*, 2020.

Setyanto, Hendro, Hendra Agus Prastyo, Muhammad Basthoni, Fika Afhamul Fuscha, and Saleh M Al-Saab. "Zodiac Light Detection Based on Sky Quality (SQM) Data: Preliminary Study." *Al-Hilal: Journal of Islamic Astronomy* 3, no. 1 (May 2021): 121–34. https://doi.org/10.1086/676819.

Shimmura, Tsuyoshi, Shosei Ohashi, and Takashi Yoshimura. "The Highest-Ranking Rooster Has Priority to Announce the Break of Dawn." *Scientific Reports* 5 (July 23, 2015). https://doi.org/10.1038/srep11683.

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