# Closed-House Biofilter Design and Performance Evaluation for Mitigating Environmental Odor Disturbances

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## Abstract

Broiler-closed houses typically lack reduction technology, leading to environmental issues, namely odor. Processing technology can be used, namely biofilters. This study aims to design and construct a closed-house biofilter and perform a test on the biofilter to reduce odors. Odors are measured by the odor gas concentration (ammonia and hydrogen sulfide) and hedonic scale by the panel method. The biofilter consisted of an odor source (closed house), a humidifier, and a biofilter reactor. Factors that influence the size of the biofilter reactor from gas removal activities include air flow rate, retention time, and air volume. The proposed biofilter can reduce the odor from the broiler. Reactor temperature, relative humidity, and bacterial activity affect odor reduction. This successful implementation of a biofilter significantly mitigates odors in a closed-house broiler, addressing a critical environmental concern.

**Keywords:** biofilter, closed house, hedonic scale, odor gas concentration, reduction efficiency

## 1. Introduction

The odor is a sensation caused by one or more chemical compounds that can affect health, the quality of life of humans, and the environment exposed to these odors when the concentration is high enough. The odor level of ambient air has quality standards to protect the community from the impacts it causes [1]. Odor level measurement can be carried out using analytical and sensory techniques as a combination technique for quantitative and qualitative characterization of odors. The analytical technique measures the odor gas concentration, while the sensory technique uses the human nose (panel method) [2]. The odor concentrations parameters consist of ammonia ($NH_3$), methyl mercaptan ($CH_3SH$), hydrogen sulfide ($H_2S$), methyl sulfide [$(CH_3)_2S$], and styrene ($C_6H_5CHCH_2$) [3]. Measuring odor with the panel method can be done using the hedonic scale [4]. Odor can come from several odor sources.

The source of the odor can come from wastewater treatment activities [5], landfill waste [6], fertilizer factories, activities in oil refineries [7], sewage sludge composting [8], the leather industry [9], and activities in the farm. However, the source of odor that has received less attention in efforts to reduce odor is livestock activities. One of the livestock activities is broiler farming. Odors from livestock activities come from the type of poultry feed, spilled feed, urine, and feces. If feces and urine are not cleaned for a long time, the feces and urine will evaporate on the surface of the air and cause an odor. The odor parameters emitted from broiler farming are $NH_3$ and $H_2S$ [10].

The total production of broilers in Indonesia in 2020 is 3,219,117 tons; in 2021, it is 3,185,698.4 tons; and in 2022, it is 3,765,573.09 tons [11]. The data shows that from 2020 to 2021, it decreased by 1.04%, and from 2021 to 2022, it increased by 18.20%. Therefore, the cultivation of broiler farms is increasing and growing by using closed houses. However, the closed

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house, which is equipped with a blower for the air exhaust system from inside the closed house, is still required to be equipped with treatment. The blower contains specific concentrations of unpleasant gases or particles that can represent the source of the odor. Odor is a normal part of broiler production due to anaerobic, aerobic, and shedding microbial activity from the animal [12]. The release of odors from animal farming practices is a significant concern for the people living near this facility. This causes a complaint and disturbs the health of animals and workers [13].

There are several types of odor processing technologies, namely technologies based on physical technologies (activated carbon adsorption, masking, and dilution diffusion), chemical technologies (plant extract spraying, wet scrubbing, combustion, and photocatalytic oxidation), biology technologies (bio trickling, bio scrubbing, and biofilter). So that farmers do not incur too many costs in operation and the processing process is more manageable, biofilters can be the technology for reducing odors from closed-house broilers [14].

The selection of biofilter as the technology to reduce odor in a closed house is because it is more environmentally friendly than chemical and physical methods, has a flexible and simple design, has low or inexpensive capital costs, and has no by-product waste [15]. Biofilters need to be used to reduce the disordered odor felt by the public by breaking down odorous gases by utilizing the ability of microorganisms, such as bacteria, that stick to porous filter media to form biofilms [16-17]. Previous research has created a biofilter model with filter media in the form of pumice, with the odor source being rotten fish, compost, chicken carcasses, and goat dung. However, this research only used a panel method with a hedonism scale. The odors reduced by the biofilter were 35% rotten fish odor, 70% goat manure odor, 82% compost waste odor, and 47% chicken carcasses odor. The subsequent research was to make a biofilter with a new source from closed-house broilers, which was carried out using a combination of measurement methods using chemical analysis ($NH_3$ and $H_2S$) and panel methods with a hedonism scale [16].

This paper aims to design and build a biofilter to reduce odor concentrations from broiler closed houses and perform a test on the biofilter to reduce odor disorders from broiler closed houses. Biofilters are constructed using filter media made from lightweight bricks that have been treated, facilitating the growth and development of bacteria responsible for odor reduction. During the research, monitoring of the temperature and relative humidity of the filter media was carried out to ensure that it matched the optimum conditions for the bacteria. The successful biofilter performance can be seen from the efficient percentage of odor reduction before and after biofiltration, determined by odor measurements employing chemical analysis and panel methods.

## 2. Methodology

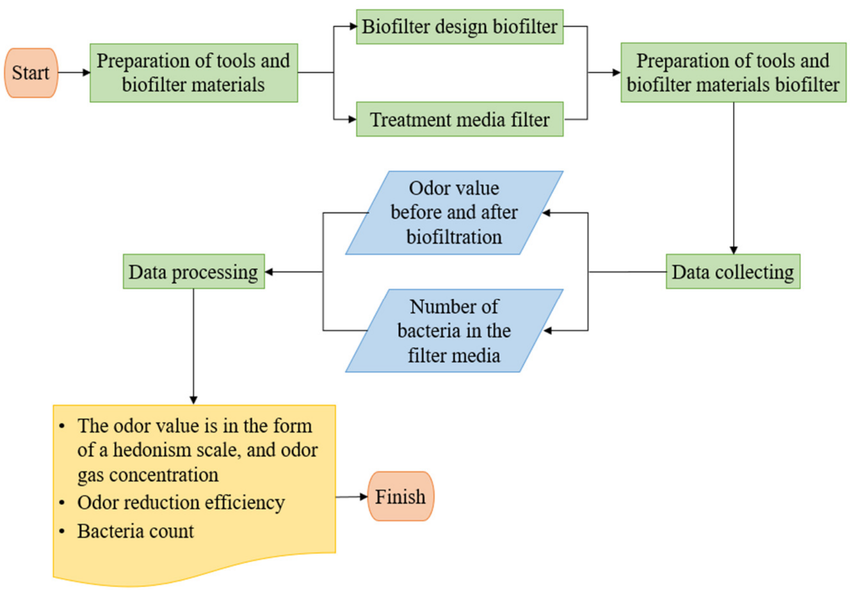


Fig. 1 Research procedure

The study was conducted from October 2022 to April 2023 at the Waste Management School, Bogor City, West Java, Indonesia. This study methodology consists of three main parts, including preparation materials and tools, construction of the biofilter, and data collecting of the odor value and number of bacteria. The study involves several steps, and Fig. 1 depicts the research procedure flowchart.

### *2.1. Equipment and material*

Test method for ammonia ($NH_3$) with the indophenol method using a spectrophotometer [18]. The equipment used in measuring ammonia levels is sampling equipment consisting of a prefilter holder, a 30 mL volume absorbent bottle, a steam trap, glass fiber (glass wool), a flow meter capable of measuring a flow rate of 1 L/min, control valves, and pumps.

In addition, equipment is required, including prefilters, 100 mL and 1000 mL volumetric flasks, 0.5 mL, 1 mL, 5 mL, and 20 mL volumetric tubes, 1 mL micropipes, 100 mL measuring cups, 100 mL beakers, 500 mL, 1000 mL, and 2000 mL, 25 mL test tube, spectrophotometer, analytical balance with an accuracy of 0.1 mg, 50 mL burette, 250 mL Erlenmeyer flask, watch glass, desiccator, oven, thermometer, barometer, and water bath. Materials used in the ammonia test include adsorbent solution, 2% sodium nitroprusside solution ($Na_2[Fe(CN)_5NO]\cdot 2H_2O$), 6.75 M sodium hydroxide (NaOH) solution, 3.7% sodium hypochlorite (NaOCl) solution, working solution hypochlorite, 45%v/v phenol ($C_6H_5OH$) solution, phenol working solution, buffer solution, 1000 µg ammonia mother liquor, 10 µg ammonia standard solution, and 1.2 M hydrochloric acid (HCl) solution for washing glassware.

$H_2S$ testing requires an absorber, air pump, spectrophotometer, and air volume meter. The air pump has a minimum flow meter capacity of 2 L/minute. The spectrophotometer is capable of operating at 670 nm. The air volume meter must be capable of measuring ±2% airflow [19]. The biofilter comprises three components: an odor source (closed house), a humidifier, and a reactor. The closed house is used as a source of odor. Humidifiers distribute air from the closed house to the reactor by maintaining air humidity. Distribution from the blower closed house to the humidifier uses a 4" polyvinyl chloride (PVC) pipe. A blower used with type inline duct fan (400-500 $m^3$/hour). The reactor is used as a filter media to reduce odors. Equipment and material used for construction biofilters include a humidifier designed to be equipped with the sprinkler, 3000 L/hour water pump, 120 L water drum, glue-sealed, glass reinforced concrete (GRC), elbow pipe 90° size 4", socket pipe size 4", angle iron, iron hollow, and aquarium pipes.

Afterward, air will be supplied to the reactor using a 4" PVC pipe. The equipment and material used in the manufacture of the biofilter reactor include lightweight bricks with a thickness of 7.5 cm, angle iron, iron hollow, wire mesh, GRC, PVC size 4", pipe tee size 4", elbow pipe 90° size 4", and cap pipe size 4". The top of the reactor is fitted with a 1/2" PVC pipe which is provided with a small hole to moisten or maintain the relative humidity of the biofilter filter media. In addition, the top of the reactor is covered with wet burlap to maintain the relative humidity of the biofilter filter media. The filter media used in the reactor to reduce odors is lightweight brick, which was previously treated by burying it in compost to form biofilm microorganisms ±2 weeks.

### *2.2. Biofilter design*

Designing and building a biofilter begins with a design created using SketchUp software. The main components of the biofilter are using a blower as exhaust air, a humidifier to maintain temperature and relative humidity, and a biofilter reactor as a place for the odor reduction process using filter media. Fig. 2 shows the 3D view of the biofilter.

The biofilter is designed considering several aspects, such as the airflow rate from the blower and retention time. It is used to determine the dimensions of the reactor. Moreover, the reactor size must be calculated in advance based on the size of the odor source. The airflow rate can be calculated by:

$$Q_{air} = A \times \text{minimum ventilation capacity} \quad (1)$$

where $Q_{air}$ is air velocity from odor source ($m^3$/minute) and $A$ is closed house area ($m^2$).

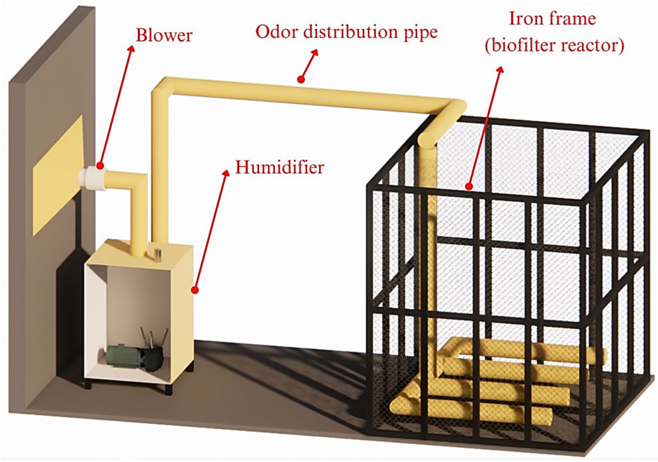


Fig. 2 3D view of biofilter

The type of blower used is according to the design airflow rate. The blower is set with a speed controller to adjust the velocity of the air released by the blower to obtain the airflow rate according to the design. A biofilter reactor carries out the odor reduction process from a closed house. The working scheme of the biofilter is presented in Fig. 3. The air velocity ($v$) of the blower can be calculated by:

$$v = \frac{Q_{air}}{A} \quad (2)$$

where $v$ is air velocity (m/hour), $Q_{air}$ is air velocity from odor source ($m^3$/jam), and $A$ is fan cross-sectional area ($m^2$)

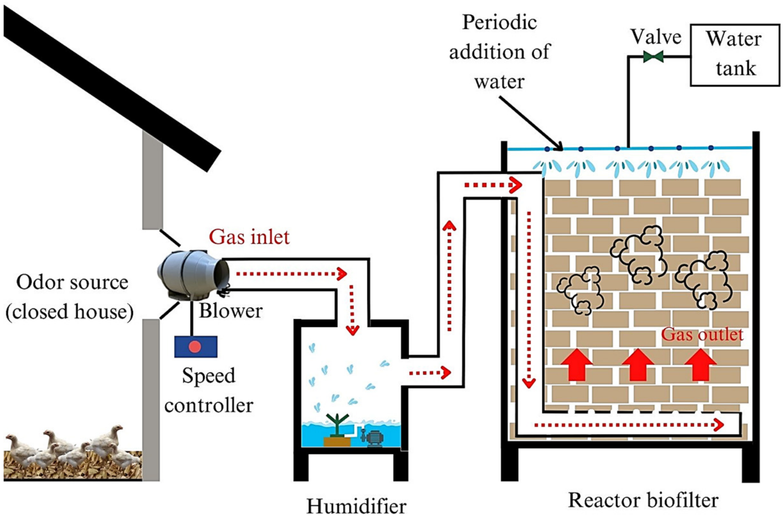


Fig. 3 Working scheme of the biofilter

### 2.3. Data collection

The data used, namely primary data in measuring gas concentrations on odor parameters, namely ammonia and hydrogen sulfide, and odor measurements using the panel method. The odor sources used are manure and broiler closed houses. Odor quality standards are shown in Table 1. Odor measurement using the panel method uses a hedonic scale, as shown in Table 2 which was collected using a questionnaire. Panelists gave a hedonic scale before and after biofiltration three times. The panelists who participated in this study were the surrounding community who did not have continuous activity at the study site. The number of panelists is eight for testing on the odor of manure and nine for testing on the source of the odor of a closed house containing ±100 broilers.

Table 1 Quality standards for odor parameter [3]

| Parameter | Quality standard (mg/L) |
|---|---|
| Ammonia ($NH_3$) | 2.0 |
| Hydrogen sulfide ($H_2S$) | 0.02 |

Table 2 Hedonic scale on the effect of odor [4]

| Hedonic scale | Effects of odor |
|---|---|
| +4 | Like extremely |
| +3 | Like very much |
| +2 | Like moderately |
| +1 | Like slightly |
| 0 | No odor |
| -1 | Dislike slightly |
| -2 | Dislike moderately |
| -3 | Dislike very much |
| -4 | Dislike extremely |

Both methods are measured during the phase of the broiler, starter, grower, and finisher. Broilers in phase-starter have an age of 1-14 days, phase-growers have an age of 15-28 days, and phase-finishers have an age of 29 days until harvest 35 days [20-22]. Therefore, odor measurements are carried out in phase-starter at the age of 10 days and phase-finisher at the age of 22 days and 31 days. The selection of odor measurements at this age aims to determine the level of odor during the broiler of the phase-starter, phase-grower, and approaching the harvest phase. However, before measurements were taken during the broiler growth phase, the measurement experiment used the odor source of manure using the panel method.

Before odor measurements using the panel method, panelists are screened first. The panelists are not sick in the respiratory tract, the nose is not blocked, and the panelists try to be the same in every odor measurement. Method screening panelists in odor measurement are required to effect odor differences from each individual and increase the efficiency and accuracy of odor assessment. The panelist screening method for measuring odor is required to determine the effect of different odors on each individual, increasing the efficiency and accuracy of odor assessment [23].

Panelists provide a hedonic scale before and after biofiltration with a total time of 45 seconds. Panelists will breathe air in the closed house (before biofiltration) for the first 15 seconds, fresh or neutral air for the second 15 seconds, and fresh air from the reactor (after biofiltration) for the third 15 seconds. Odor measurements using the panel method are repeated three times for each panelist. Odor measurements after biofiltration using the panel method are assisted by equipment like a nylon hose and a glass funnel, as shown in Fig. 4.

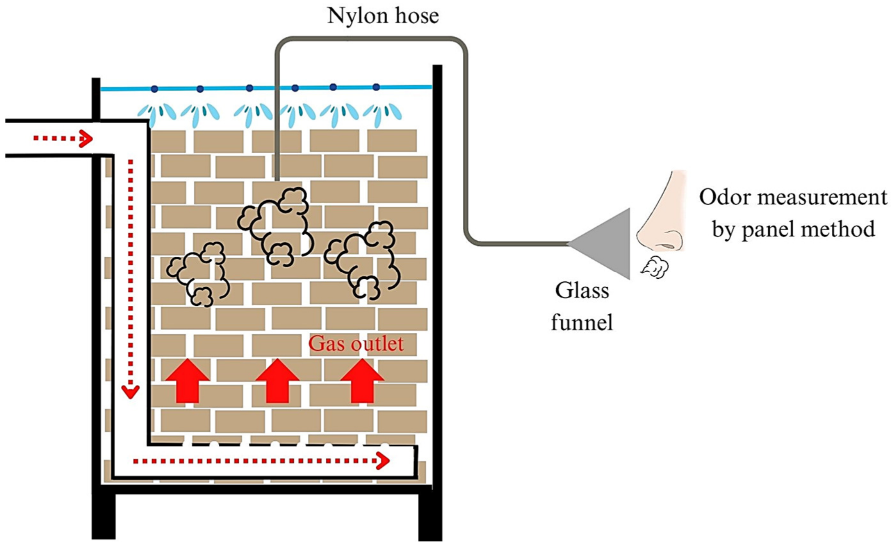


Fig. 4 Odor measurement using the panel method

Odor measurements by chemical analysis and the panel method are carried out simultaneously for 1 hour to compare the results of the two methods. The results of the chemical analysis test and the odor hedonic scale according to the human sense of odor show the same level of odor. Odor measurements are made before and after biofiltration to determine odor reduction efficiency. Odor reduction efficiency can be calculated by [15]:

$$R = \frac{C_{in} - C_{out}}{C_{in}} \times 100 \tag{3}$$

where $R$ is reduction efficiency (%), $C_{in}$ is odor concentration or hedonic scale before biofiltration, and $C_{out}$ is odor concentration or hedonic scale after biofiltration.

## 3. Results and Discussion

The discussion of this study comprises two main parts: biofilter design and construction and biofilter performance testing. The biofilter is designed with an optimal size tailored to the specific odor source under examination, ensuring it is neither too big nor too small. However, what is even more noteworthy is the biofilter's success in effectively reducing odors.

### 3.1. Design and construction of biofilter

The biofilter comprises three components: an odor source (closed house), a humidifier, and biofilter reactors. The odor source comes from a closed house of 500 cm × 300 cm × 285 cm, up to the volume closed house of 42.75 $m^3$ and an area of 15 $m^2$. Minimum ventilation capacity closed houses by 0.3-0.6 $m^3$/minute/$m^2$ [24], up to an average of 0.45 $m^3$/minute/$m^2$. The closed house airflow rate obtains 6.75 $m^3$/minute or 405 $m^3$/hour. Therefore, the type of blower uses a duct fan, which has an airflow rate of 400-540 $m^3$/hour. The velocity of the air is set with a speed controller of 7.3 $m^3$/second to obtain the air flow rate according to the design. The airflow rate from a closed house, influenced by the closed house area and the minimum ventilation capacity, becomes a template for determining the number of blowers and blower air flow rate.

Table 3 Design criteria of biofilter reactor

| Parameter | Amount | Unit |
|---|---|---|
| Factors that determine the biofilter reactor's size | | |
| Long closed house | 500 | cm |
| Width of closed house | 300 | cm |
| Height of closed house | 285 | cm |
| Area of closed house | 15 | $m^2$ |
| Rate minimum ventilation capacity at closed house | 0.45 | $m^3$/minute/$m^2$ |
| Airflow rate (Q) | 405 | $m^3$/hour |
| | 6.75 | $m^3$/minute |
| Retention time (T) | 45 | seconds |
| Air volume (V) | 5.06 | $m^3$ |
| Size of the biofilter reactor | | |
| Filter media volume | 3.04 | $m^3$ |
| Air volume + filter media volume | 8.10 | $m^3$ |
| Long of reactor | 180 | cm |
| Width of reactor | 225 | cm |
| Height of reactor | 200 | cm |

The retention time is 45 seconds. Therefore, the air volume is 5.06 $m^3$. The volume used for filter media is 3/8 of the reactor volume of 3.04 $m^3$, and the air volume is 5/8 of the reactor volume of 5.06 $m^3$; therefore, the total volume of the reactor is 8.1 $m^3$. Therefore, the size of the biofilter reactor is 180 cm × 225 cm × 200 cm, as shown in Table 3. The size of the biofilter reactor is 180 cm × 225 cm × 200 cm, adjusting the available floor area in the field. If the length or width of the floor in the field is not too large, then the height of the biofilter reactor can be increased. Determining the size of the reactor to be made depends on the size of the odor source and the number of broilers being cultivated. The bigger the odor source and the more cultivated broilers, the bigger the biofilter reactor. Apart from that, other factors influence the size of the biofilter reactor from gas removal activities from closed-house broilers, including air flow rate, retention time, and air volume. The results of the built biofilter are shown in Fig. 5.


Fig. 5 The biofilter of closed house

The biofilter testing experiment commences with the source of the odor from manure using only the panel method, then proceeds with measuring the odor gas concentration with the hedonic scale at the source of the broiler odor, as shown in Fig. 6. Odor measurement experiments using odor sources from manure. After the biofilter is optimal, the biofilter performance test is continued with the odor source from the closed-house broiler.

(a) Manure (b) Broilers

Fig. 6 Odor sources used in biofilter testing

The filter media, consisting of lightweight bricks, is treated by burying in compost for approximately two weeks, as shown in Fig. 7. The odor reduction efficiency ($NH_3$ and $H_2S$) depends on the filter media material and the mixture of filter media and compost. Micro-nutrients required for microbial growth are supported by compost [25]. The abundance of bacteria in the most dominant biofilter, Bacillus sp., is 31.90% [6]. The number of bacteria in the filter media from laboratory results, namely Bacillus sp., is $3.6 \times 10^6$ CFU/g. The sample tested was a biofilm that had adhered to the surface of the light brick filter media. The decreased biological activity and bacterial population decreased the biofilter reactor performance [26]. Therefore, bacterial growth must be maintained by monitoring the biofilter reactor.

Monitoring the biofilter reactor's temperature (T) and relative humidity (RH) to determine the filter media's performance in reducing odors. Reactor temperature affects the growth of bacteria in the filter media. High temperature and suitable relative humidity increase biodegradation efficiency due to their influence on the speed of chemical reactions and the metabolic rate of microorganisms. Microbial metabolic reactions influence the removal of $H_2S$ and $NH_3$ in an odor source [6].

(a) Process treatment of filter media (b) Reactor filter media: lightweight bricks

Fig. 7 Biofilter filter media

The temperature and relative humidity measurements are carried out during the odor measurement process. This monitoring is carried out at the preparatory closed house and during the broiler breeding from 1 day to 31 days old, with the results as shown in Fig. 8. The biofilter reactor that has been built has the highest average temperature and relative humidity of 31.5 °C and 96.5%, respectively. The temperature and relative humidity of the biofilter reactor on odor measurements with the odor source of manure, broiler 10 days old, broiler 22 days old, and broiler 31 days old, are 27.9 °C, 30.6 °C, 29.2 °C, 29.7 °C and 88%, 96%, 95%, 96%, respectively.

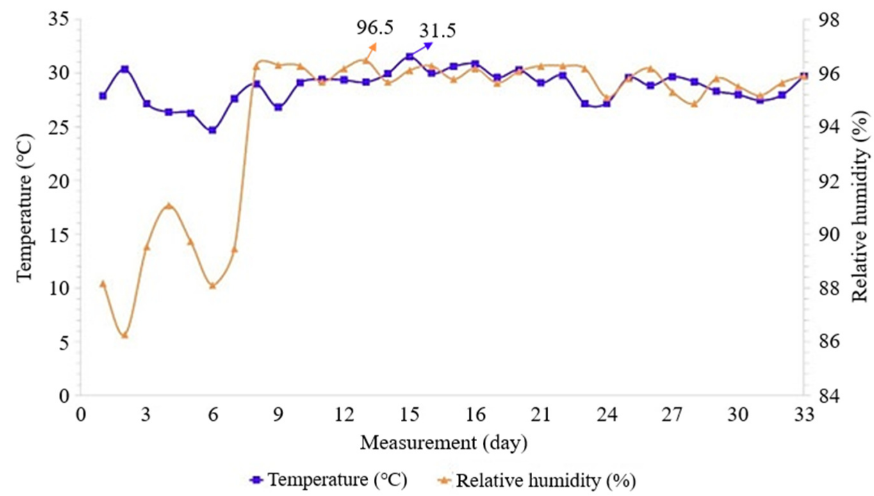


Fig. 8 Results of measurements of temperature and relative humidity in the biofilter reactor

Table 4 Temperature (T) and relative humidity (RH) in the biofilter reactor

| Parameter | Odor source | | | | Optimum conditions |
|---|---|---|---|---|---|
| | Manure | Broiler (10 days old) | Broiler (22 days old) | Broiler (31 days old) | |
| T (°C) | 27.9 | 30.6 | 29.2 | 29.7 | 25-35 °C [16]<br>25 °C [27] |
| RH (%) | 88 | 96 | 95 | 96 | 95-100% [28] |

Fig. 9 Wet burlap to maintain relative humidity in the reactor

These results follow the optimum conditions as shown in Table 4. The relative humidity at the time of odor measurement using the manure odor source had not yet reached the optimal relative humidity. Apart from that, at the preparatory stage for broiler cultivation and the start of broiler cultivation around the relative humidity measurements on days 1 to 9, it still had not reached the optimum relative humidity. The relative humidity obtained fluctuates below 95%. Therefore, the top of the reactor was covered with wet burlap to maintain the relative humidity of the reactor so that it could reach optimum relative humidity, as shown in Fig. 9. The relative humidity in the subsequent odor measurement has reached the appropriate relative humidity. Based on the data obtained, the higher the temperature, the higher the relative humidity.

### 3.2. *Performant test of biofilter*

The biofilter has reduced odor with excellent odor efficiency, as shown in Table 5 and Fig. 10. The odor reduction efficiency of the ammonia parameter is 50-80%. The highest decrease in odor occurred in the grower phase, namely when measuring the odor of a 22-day-old broiler by 80%. Furthermore, the odor concentration in the ammonia parameter is the highest compared to the starter phase (10 days) and the finisher phase (31 days). This could be because broilers eat much feed in the grower phase so that more feces are produced. The biofilter's odor reduction efficiency can be obtained from changes in the odor gas concentration before and after biofiltration. Odor reduction efficiency can only be calculated on the ammonia parameter. The odor reduction efficiency of the hydrogen sulfide parameter cannot be calculated because some of the results of the hydrogen sulfide's odor gas concentration are < 0.003 because it is smaller than the detection limit of the equipment.

Table 5 Odor reduction efficiency of odor parameters

| Odor measurement (broiler age) | Parameter | Quality standard (mg/L) | Measurement result (mg/L) | | Odor reduction efficiency (%) | Conclusions |
|---|---|---|---|---|---|---|
| | | | Before biofiltration | After biofiltration | | |
| 10 days | $NH_3$ | 2.0 | 0.4 | 0.2 | 50.0 | Satisfy the standard |
| | $H_2S$ | 0.02 | < 0.003 | < 0.003 | - | Satisfy the standard |
| 22 days | $NH_3$ | 2.0 | 1.0 | 0.2 | 80.0 | Satisfy the standard |
| | $H_2S$ | 0.02 | 0.008 | < 0.003 | - | Satisfy the standard |
| 31 days | $NH_3$ | 2.0 | 0.9 | 0.3 | 66.67 | Satisfy the standard |
| | $H_2S$ | 0.02 | < 0.003 | < 0.003 | - | Satisfy the standard |

Description: Quality standard [3]
< is smaller than the detection limit

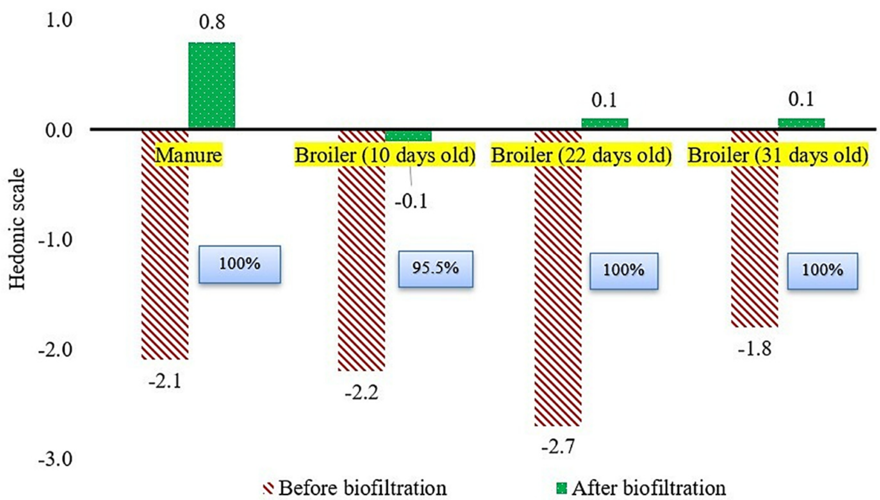


Fig. 10 Odor reduction efficiency using the panel method

Odor reduction efficiency with the panel method is 95.5-100.0%, as shown in Fig. 10. The odor reduction efficiency of the manure odor source was 100% due to a change in the hedonism scale from -2.1 before biofiltration to 0.8 after biofiltration. The odor reduction efficiency of the odor source for the 10-day-old broiler was 95.5% due to a change in the hedonism scale from -2.2 before biofiltration to -0.1 after biofiltration. The odor reduction efficiency of the odor source for the 22-day-old broiler was 100% due to changes in the hedonism scale from -2.7 before biofiltration to 0.1 after biofiltration. The odor reduction efficiency of the odor source for a 31-day-old broiler was 100% due to a change in the hedonism scale from -1.8 before biofiltration to 0.1 after biofiltration. Therefore, biofilters have been able to reduce odors. This can be seen from the hedonic scale provided by the panelists who experienced a change from a negative odor impression before biofiltration to a positive odor impression after biofiltration. This successful implementation of a biofilter significantly mitigates odors in closed-house broiler facilities, addressing a critical environmental concern.

The success of biofilters in reducing odors is because microorganisms will consume odorous substances during the biofiltration process. The product of this biodegradation is $CO_2$, water vapor, and heat. This biodegradation can change most odorous substances into odorless substances. Most $H_2S$ will be bio-oxidized to sulfate, while $NH_3$ will turn into nitrates. If suitable organic matter is present in the media, the bacteria use it as a source of carbon, energy, and nitrogen [6].

Moreover, calculating the average hedonic scale provided by the panelists, the standard deviation (STD) is also calculated to see the variation in the hedonic scale data from the panelists. The standard deviation obtained is shown in Table 6. The standard deviation is smaller than the average hedonic scale. This shows that the average hedonic scale is a good representation of the overall hedonic scale data provided by the panelists. However, there is a standard deviation more significant than the average value in the odor measurement data at the age of 10 days of broilers.

This can happen because the measurement of odor using the panel method is subjective; therefore, the hedonic scale of each panelist has various data variations. Therefore, measuring odors using the panel method requires screening and training of panelists in assessing odors to prevent data discrepancies between measuring odor concentrations using instruments and odor measurements using the panelist method [29]. This raises concerns, namely when the concentration of odorous gas is still low or below standard quality, but the panelists already smell an unpleasant odor.

Table 6 Odor reduction efficiency using the panel method at the time of odor measurement

| Odor source | Hedonic scale (average ±STD) | | Odor reduction efficiency (%) |
|---|---|---|---|
| | Before biofiltration | After biofiltration | |
| Manure | -2.1 ±0.8 | 0.8 ±0.4 | 100.0 |
| Broiler (10 days old) | -2.2 ±0.7 | -0.1 ±0.4 | 95.5 |
| Broiler (22 days old) | -2.7 ±0.5 | 0.1 ±0.1 | 100.0 |
| Broiler (31 days old) | -1.8 ±0.7 | 0.1 ±0.1 | 100.0 |

## 4. Conclusions

This study analyzes the performance of biofilters in reducing the odor of closed houses using a new filter media, namely lightweight brick. The construction biofilter comprises three components: the odor source (closed house), the humidifier, and the biofilter reactors. The closed house measures 500 cm × 300 cm × 285 cm and accommodates approximately 100 broilers. Consequently, the necessary biofilter reactor dimensions are 180 cm × 225 cm × 200 cm. The size of the biofilter reactor will need to increase with the rise in both the odor source and the number of broilers.

Apart from that, other factors influence the size of the biofilter reactor from gas removal activities from closed-house broilers, including air flow rate, retention time, and air volume. The airflow rate is 405 $m^3$/hour with a retention time of 45 seconds. The filter media is lightweight brick. The filter media contains $3.6 \times 10^6$ CFU/g, Bacillus sp. The biofilter reactor temperature is 27.9-30.6 °C, and relative humidity is 88-96%. The odor gas concentration of ammonia and hydrogen sulfide parameters before and after biofiltration meets the quality standard. The odor reduction efficiency of the ammonia parameter is 50-80%. Using the panel method, the odor reduction efficiency ranges from 95.5% to 100.0%.

In conclusion, this successful implementation of a biofilter significantly mitigates odors in closed-house broiler facilities, addressing a critical environmental concern. For further research, different filter media can be explored for the closed-house broiler odor source. This is particularly crucial if a filter medium is found to be both more cost-effective and efficient in reducing odors.

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## Conflicts of Interest

The authors declare no conflict of interest.

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