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Design of an exhaust fan with activated charcoal in a broiler closed houses for ammonia gas mitigation

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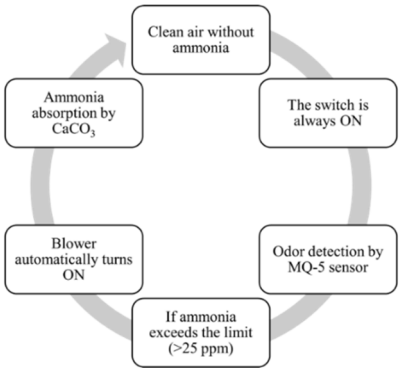
Abstract

Currently, the broiler chicken coop has changed from an opened house system to a closed house system. The problem that arises with the closed house cage system is farmers only think about the health and productivity of broiler chickens in the cage, without thinking about the environmental impact caused by the ammonia gas released from the cage. It is necessary to modify the exhaust fan design with activated charcoal in closed house broilers to mitigate ammonia gas on the inside and outside of broiler chicken coop. Tools and materials used in designing the tool are Box Panel, Wireless Sensor Network, Chimney, Raspberry Pi + LCD, Activated Charcoal, MQ-5 sensor, Electric sensor & controller unit and PCB. The exhaust fans system with activated charcoal is able to absorb unpleasant odors in broiler closed houses. This tool system uses an absorbent principle that works to absorb ammonia using $CaCO_3$ activated charcoal with an intensity of time of 14 – 16 minutes to reduce ammonia levels to 25 – 30 ppm.



Keywords: Activated charcoal; Ammonia gas; Broiler close house; Exhaust fan

1. Introduction

Broiler farming is a livestock sub-sector that is currently growing rapidly and has the highest demand compared to other types of livestock in Indonesia. The increasing consumer demand for broiler chicken meat has caused a surge in the number of broiler chicken populations. Based on data from the Central Statistics Agency in 2018 to 2020, shows that the population of broiler chickens always increases every year, especially in Java and Bali [1]. The increasing population of broiler chickens has a positive impact on the availability of sufficient meat in Indonesia [2]. However, it also has a negative impact on chickens, humans, and the environment, this is due to the increasing number of manure or chicken manure in the cage. Chicken manure that collects in the coop and accumulates for days in large quantities can produce various harmful gasses, one of which is ammonia gas [3].

Ammonia (NH_3) gas is a caustic compound that can damage health. The concentration level of ammonia in livestock pens, especially poultry can reduce appetite, reduce egg production,

respiratory tract infections, increase susceptibility to the Newcastle disease virus, increase the incidence of airway infections (airsacculitis), inflammation of the cornea of the eye (keratoconjunctivitis), and increase the prevalence of *Mycoplasma gallisepticum.* If inhaled by humans, ammonia can cause respiratory problems, irritation of the eyes, nose, throat and even if it reaches a certain concentration of ppm (parts per million), it can be life threatening. Ammonia threshold value set for humans and animals is 25 ppm, with a maximum limit of direct contact for 8 hours, if the ammonia concentration reaches 35 ppm then the maximum limit for direct contact is 10 minutes. Ammonia concentrations that reach 1,000 – 1,500 ppm can cause dyspnea, chest pain and pulmonary edema which can be fatal [4].

Currently, the broiler chicken coop has changed from an opened house system to a closed house system. The positive side of the closed house system is the farmer can control the microenvironment in the cage, so that it can be adjusted to the needs of broiler chickens. However, the negative side of the closed house system is the excreta that collects in the cage causes high levels of ammonia gas. It can be minimized by using an exhaust fan that can remove air on the inside and outside of the cage, so the ammonia gas can be removed.

The problem that arises today with the closed house system is the farmers only think about the health and productivity of broiler chickens in the cage, without thinking about the environmental impact caused by the ammonia gas released from the cage. Ammonia gas that is released from the closed house using an exhaust fan causes the environment around the cage to have high levels of ammonia which harm the surrounding environment. In addition, ammonia gas which is directly discharged into the environment causes global effects because ammonia gas contributes to the formation of nitrogen oxide gas which is a greenhouse gas. Moreover, ammonia in the atmosphere can cause acid rain, which ultimately results in acidification and eutrophication of soils and rivers [5]. Currently, the largest emission of ammonia gas comes from the livestock industry, which is around 80 – 90% [6]. It is necessary to modify the exhaust fan design with activated charcoal in closed house broilers to mitigate ammonia gas on the inside and outside of broiler chicken coop, so there is a balance between the health of the chickens in the cage and the health of the environment outside the cage.

2. Materials and Methods

The stages of this research are firstly to make the design of the system, manufacturing of the system and testing the functional of the system, then if it is appropriate, the system will be immediately tested in a closed house cage.

Design of a Modified Exhaust Fan Modification on Broilers Close House

The design of a modified exhaust fan in a broiler closed house by using Autocad can be shown in Fig. 1. Fig. 2 shows the design of the application of modified exhaust fans on broilers close house. The exhaust fan design for ammonia gas mitigation is needed so that ammonia gas coming out of the closed house can be minimized. The solution to be able to capture the ammonia gas released by the exhaust fan is by making an exhaust fan chimney in which a filter in the form of activated charcoal is placed.

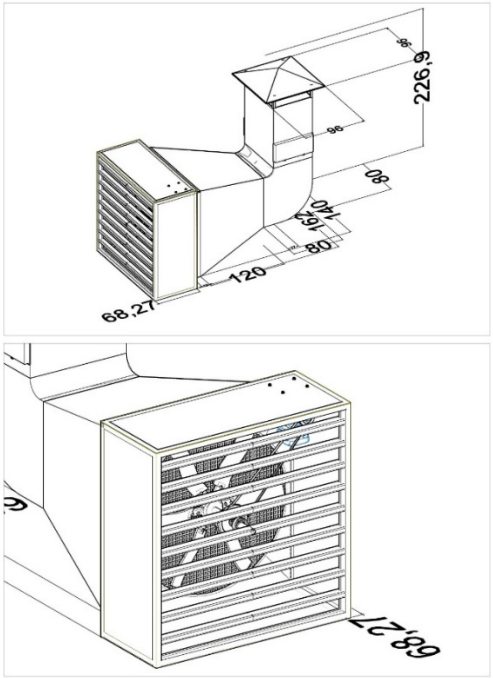


Fig. 1 Design of a modified exhaust fan.

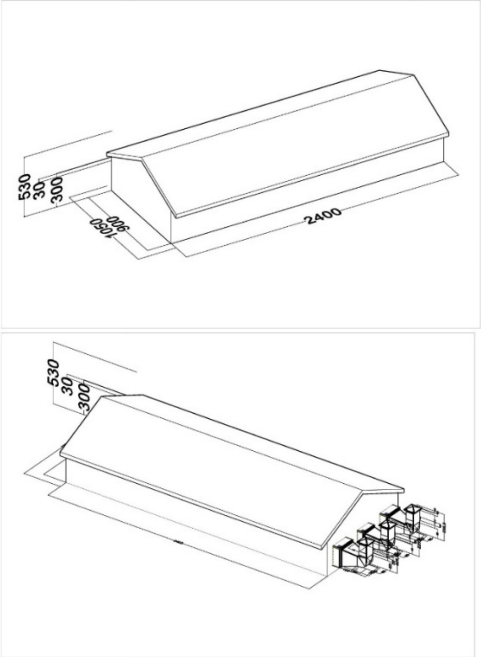


Fig. 2 Design of the application of modified exhaust fans in broilers close house.

Manufacture of Modified Exhaust Fan in Broilers Close House

Tools and materials used in designing the system are box panel, wireless sensor network, chimney, raspberry Pi + LCD, activated charcoal, electric sensor & controller unit and PCB. The working principle of the system can be seen in Fig. 3. The switch is always on which will help in the automatic working process of the tool. Ammonia gas detection by the MQ-5 sensor is an initial process where in principle activated carbon from charcoal will absorb ammonia gas in the cage and will reduce the smell of ammonia gas in the cage. The exhaust fan automatically turns on when the level of ammonia gas in the enclosure exceeds 25 ppm. Absorption of smelly air due to excessive levels of ammonia by activated charcoal or $CaCO_3$. Activated charcoal $CaCO_3$ has a very important function in the absorption of ammonia in tool components. Charcoal is a black residue in the form of a porous solid containing 85 – 95% carbon, produced by removing water content and volatile components from carbon-containing materials by heating at high temperatures [7]. Jamilatun and Setyawan [8] define that charcoal is a black residue resulting from combustion in the absence of oxygen containing carbon in a solid and porous form, such as wood or other biomaterials. Some of the pores are still closed with hydrocarbons and other organic compounds. Its components consist of fixed carbon, ash, water, nitrogen, and sulfur. Commercial activated charcoal is mostly used as an adsorbent in various applications such as being used in oil spill cleaning, drinking water filters, air filters, and soil improvement. According to Kurniati [9], Activated charcoal is a form of carbon that is specially treated to produce a very large surface area, ranging from 300 – 2000 m^3gr^{-1}. The large surface area of the structure in the pores of activated carbon can be developed, this structure provides the ability of activated carbon to absorb gases and vapors from gas and can reduce substances from liquid. Clean air after the absorption process, both inside and outside of the cage.

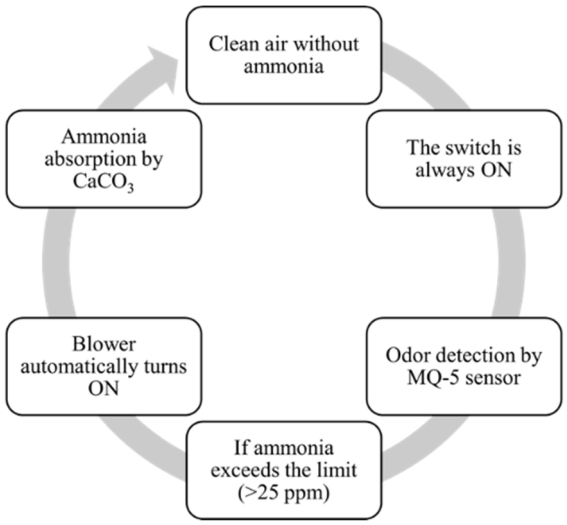


Fig. 3 The working principle of the modified exhaust fans system with activated charcoal in broilers close house.

The installation system

Integrated sensor which consists of ammonia, temperature and humidity sensors. The Ammonia sensor used is the MQ137 type. While the humidity and temperature sensors use the AM2315 sensor. The MQ137 sensor outputs analog data which is then read by the ADC pin

on the microcontroller. While the AM2315 sensor uses I2C data communication. ATMega328 microcontroller is used as a controller on the integrated sensor. Fig. 4 shows the installation and block diagram of the integrated sensor system installed in the closed house.

On the main controller, there are 2 modes. Automatic mode and manual mode. If you enter manual mode, the exhaust fan can be activated directly via a smartphone. If you enter automatic mode, the three exhaust fans will be activated based on the parameters stored in the cloud database. There are 12 parameters for the activation of the three fans. Fan 1 NH3 low level, Fan 1 NH3 High level, Fan 2 NH3 low level, Fan 2 NH3 high level, Fan 3 NH3 low level, Fan 3 NH3 High level, Fan1 temperature low level, Fan 1 temperature high level, Fan 2 temperature low level, Fan 2 temperature high level, Fan3 temperature low level, and Fan 3 temperature high level.

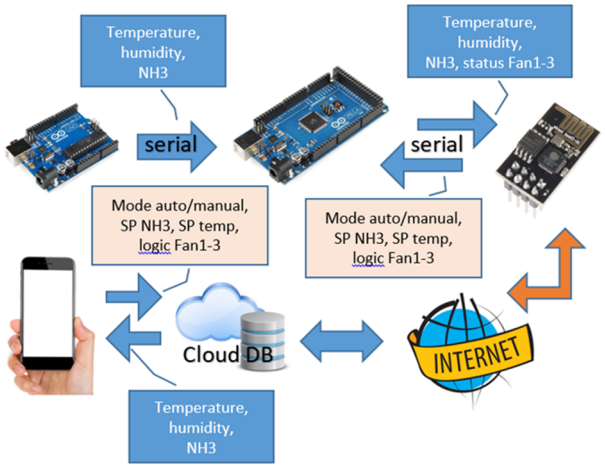
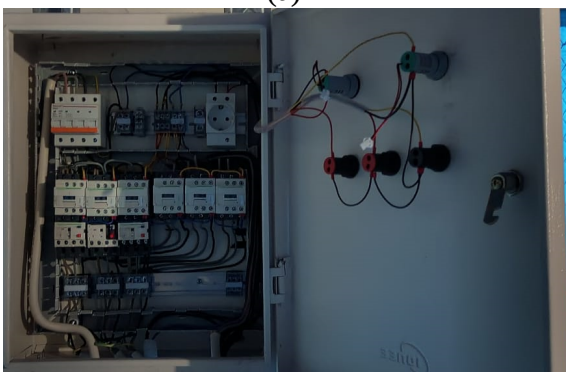


Fig. 4 The installation and block diagram of the integrated sensor system installed in the closed house.

3. Results and Discussion

The design of a modified exhaust fan in a broiler close house is an alternative innovation of odor absorption using the MQ-5 sensor principle and the help of activated charcoal. By using the principle of detection and absorbent based on automatic, the activated carbon in the tool can help absorb ammonia odors in closed house broilers.

(a)



(b)

(c)

Fig. 5 (a) Exhaust fan in broilers close house, (b) Exhaust fan system and (c) Modified exhaust fan system.

Functional testing of the Modified Exhaust Fan in Broilers Closed House found that the tool can absorb ammonia and can also detect how much ammonia levels are in the farm. This tool

has been applied and the results are able to absorb ammonia at 25 – 30 ppm in 14 – 16 minutes and within a day the unpleasant odor due to high levels of ammonia sometimes decreases. The results of testing the absorption of ammonia gas against time can be seen in Fig. 6.

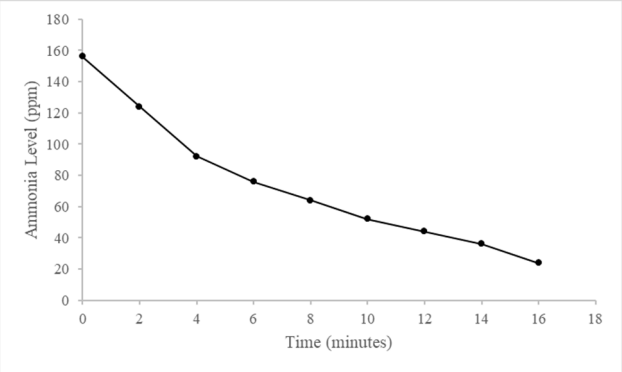


Fig. 5 Decreased ammonia levels in broiler close house.

Ammonia concentration at certain levels can cause various disorders. The threshold limit value for ammonia in poultry is 25 ppm, but some European scientists recommend a much lower concentration threshold of 10 ppm. Actually, this ammonia is lighter than air, so it is easily dispersed by air circulation. However, because it is produced in cages, the ammonia is difficult to spread and is very influential on the chickens in the cage.

With maximum absorption of activated charcoal the adsorbent or most of the adsorbents are highly porous materials, and adsorption takes place mainly on the pore walls or in certain areas within the particle. An adsorbent is considered as a good adsorbent for adsorption in terms of time. The operating time is divided into two, namely the absorption time to the desired composition and the regeneration/drying time of the adsorbent. The faster the two variables, the better the performance of the adsorbent [9].

The absorption mechanism according to [10], are as follows:

a. The adsorbate molecules move towards the outermost layer of the adsorbent.

b. Activated carbon in a group unit has a large pore surface area so that it can absorb the adsorbate.

c. Some of the adsorbate is adsorbed on the outer surface, but most of it is adsorbed in the pores of the adsorbent by diffusion.

d. If the adsorption capacity is still very large, most of the adsorbate molecules will be adsorbed and bound to the surface. However, if the adsorbent pore surface is saturated with adsorbate, two possibilities will occur, namely: A second, third and so on adsorption layer is formed and a second, third and so on adsorption layer is not formed so that the adsorbate that has not been adsorbed will continue to diffuse out of the pore.

The adsorption of gasses by solids is characterized by the following:

a. Adsorption is selective, meaning that an adsorbent can absorb a large amount of gas, but absorbs other gasses in smaller amounts.

b. Adsorption occurs very quickly, namely the speed of adsorption decreases with the increasing amount of gas absorbed.

c. Adsorption depends on the surface area of the adsorbent, the more porous the adsorbent, the greater the adsorption power.

d. The amount of gas adsorbed per unit weight of the adsorbent depends on the partial pressure of the gas, the greater the pressure, the more gas is absorbed.

According to [10], the initial process of gaseous contaminants is in contact with the adsorbent at the very top of the adsorption column. The crystalline region has a thickness of 0.7 – 1.1 nm, much smaller than that of graphite. It indicates the presence of 3 or 4 layers of carbon atoms with approximately 20 – 30 hexagons filled in each layer. The voids between the carbon crystals are filled with amorphous carbons which are three-dimensionally bonded to other atoms, especially oxygen. This irregular arrangement of carbon is punctuated by cracks and fissures called pores and is mostly cylindrical. Besides to containing carbon, activated carbon also contains small amounts of hydrogen and oxygen which are chemically bonded to various functional groups such as carbonyl, carboxylate, phenol, lactone, quinone, and ether groups. Surface oxides are often derived from the raw material or can also be formed by reaction with air or water vapor.

These oxides are usually acidic so that they decrease to the activated carbon. Functional groups are formed during the activation process by the interaction of free radicals on the carbon surface with atoms such as oxygen and nitrogen. This functional group makes the activated carbon surface chemically reactive and affects its adsorption properties [11]. In this case ammonia or NH_3 has a boiling point of – 33 °C freezing point – 78 °C vapor pressure 10 atm, specific gravity (H_2O = 1): 0.682 at 4 °C percent volatile 100% appearance and odor: colorless gas/ liquid but has a pungent odor. Busca *et al.* [12] with the help of activated carbon to absorb gas, activated carbon also has an active period of 60 hours after which the activated carbon dies and can be reactivated.

The adsorption process can occur between solids with solids, gasses with solids, gasses with liquids, and liquids with solids [13]. According to [14], adsorption is the process of mass transfer of adsorbate from the mobile phase (adsorbate carrier fluid) to the surface of the active sites on the surface of the adsorbent. There are two methods of adsorption, namely physical adsorption (physicosorption) and chemical adsorption (chemoisorption) [15]. Physical adsorption occurs due to differences in energy or electric attractive forces (Van Der Waals force), so that the adsorbate molecules are physically bound to the adsorbent molecules. While chemical adsorption is a strong chemical bond and cannot be reversed (irreversible) because in its formation it requires activation energy, so to release it requires energy that is relatively the same as the energy of formation. The adsorption kinetics in NH_3 absorption can be described by the Freundlich adsorption isotherm model. Freundlich's adsorption isotherm theory assumes that the pore surface of the adsorbent is heterogeneous with non-uniform adsorption heat distribution. The form of the Freundlich equation is as follows [13].

$$\log \log x / m = \log \log K_f + 1/n \log \log C_e \quad (1)$$

Where, x = amount of adsorbate absorbed (mg), m = weight of adsorbent (g), C_e = equilibrium concentration (mgL^{-1}), K_f = intercept, indicating the adsorption capacity of adsorbent, 1 / n = slope which shows the diversity of adsorption and concentration.

4. Conclusion

The exhaust fans system with activated charcoal is able to absorb unpleasant odors in the broiler's closed house. This tool system uses an absorbent principle that works to absorb ammonia using $CaCO_3$ activated charcoal with an intensity of time of 14 – 16 minutes to reduce ammonia levels to 25 – 30 ppm.

5. Suggestions

Further research is to vary the type of material that can reduce ammonia levels.

6. Acknowledgement

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