Dry filtration technology application with activated carbon media to remove odor ammonia emissions from production process feed mill industry

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Abstract. A pilot project research has been conducted to eliminate odor pollution from the feed mill industry. The feed industry in Indonesia has grown, especially in poultry feed production produced in modern feed mills equipped with pelleting technology. This industry is also having an environmental impact in the form of air pollution of its production activities. The laboratory analysis showed that ammonia has emitted, and it was the dominant parameter as the cause of odor in air pollution. This research aims to remove ammonia emissions using dry filtration technology with activated carbon as the filter media in the upright reactor. The reactor is designed from stainless steel material, consisting of 3 trays. The distance between trays is 300 mm, the dimensions of the tray are L.2430 mm, W.1815 mm, H.600 mm, the tray hole diameter is 3 mm. The average gas flow rate is 200-300 Nm³/min. Activated carbon used granules, size 6-8 mm, 200 mm thick in the tray. The results showed that the efficiency of ammonia removal was 81.96%-94.40% and had met the quality standards. This technology is feasible to control ammonia as an odor pollutant in the feed mill industry.

1. Introduction

The feed mill industry, mainly poultry feed, is critical in sustaining food availability because 65 percent of animal protein needs are met from chicken meat and eggs. The growth of the feed industry in Indonesia is estimated at around 5-6% per year. In 2019 production reached 19.5 million tons, while in 2020, it increased to 20.67 million tons. The Directorate General of Livestock and Animal Health stated that the consumption of chicken meat in Indonesia in 2019 reached 12.13 kg per capita per year, while in 2020, it increased to 12.79 kg per capita per year, an increase of 5.4% [1].

The feed poultry industry in Indonesia has grown and produced in modern feed mills equipped with pelleting technology. The growth and development of the feed industry are also supported by the availability of abundant local raw materials such as corn [2] and other materials such as soybean meal, Meat & Bone Meal (MBM), micro components such as minerals and vitamins imported from abroad [3].

People who live near the feed industry often complain of an unpleasant odor from its activity. The general process in poultry feed production is milling; mixing and conditioning; palletizing and cooling; crushed and packaging steam conditioning and pelleting have an essential role in producing good...
quality feed [4], and also having an impact in the form of air pollution that emitted to the environment as an unpleasant odor. The source of unpleasant odors occurs at the stages of the mixing and conditioning process. The effect of the conditioning process, the raw material occurs in the evaporation process of short-chain fatty acids, protein denaturation, vitamin damage, and the Maillard reaction. The Maillard reaction is a polymerization reaction of reducing sugars with primary amino acids to form a brown melanoidin compound; this process occurs due to heating [5].

In 2020, the BBTPPI laboratory conducted emission monitoring for odor pollutants such as ammonia and hydrogen sulfide in one of the feed industries in Central Java. The results showed that the ammonia concentration was 6.918 mg/Nm$^3$ and <7 mg/Nm$^3$ for hydrogen sulfide (H$_2$S). The concentration of ammonia emissions exceeds the permissible requirements, namely a maximum of 0.5 mg/Nm$^3$ by the Decree of the State Minister for the Environment of the Republic of Indonesia No. 13 of 1995 [6]. Ammonia (NH$_3$) is a toxic gas that is harmful to humans and the environment [7] and is also a precursor of Nitrous Oxide (N$_2$O), which contributes to an increased greenhouse effect and ozone layer depletion. Ammonia is emitted from complex physical processes controlled by factors of temperature, surface area, exposure to emission sources, and air velocity [8].

Many technologies control ammonia emissions, such as absorption by liquids, adsorption by solids, biochemical process, thermal combustion, and catalytic process [9]. Each of these technologies has advantages and disadvantages. Technologies that do not cause other problems such as wastewater are dry technologies such as adsorption by solids. Activated carbon is an adsorbent that can absorb ammonia in the form of gas with a short contact time [10,11].

This pilot project research aims to eliminate ammonia gas that causes odor from the feed mill process factory. The feed mill industry, which will be the pilot project in implementing this research, has a 20-25 tons/hour production capacity. The factory operates in 2 production shifts (16 Hours). This research will apply dry filtration technology innovation with activated carbon filter media as a deodorizer emitted from the processing unit feed mill factory. The reactor design chosen is prioritized to save space and materials.

2. Methodology

2.1 Location and time

This research was conducted in a poultry feed industry located in the province of Central Java. This implementation of research carried out in 2020.

2.2 Ammonia odor testing

The test was carried out using the indophenol method SNI 19-7117.6-2005 to determine ammonia concentration in the flue gas.

The equipment used for sampling is an impinger, suction pump, flowmeter, and tripod. The analysis equipment is a spectrophotometer brand Shimadzu UV-1800 type and glassware from Pyrex. All equipment used is calibrated.

The chemicals used are boric acid (H$_3$BO$_3$), phenol (C$_6$H$_5$OH), sodium hydroxide (NaOH), sodium nitroprusside (Na$_2$HPO$_4$.7H$_2$O), sodium hypochlorite (NaOCl), ammonium sulfate (NH$_4$)$_2$SO$_4$, and hydrogen peroxide (H$_2$O$_2$). All materials are pure analysis grade from Merck.

2.3 Design of dry filter equipment

The dry filtration equipment is designed with three tray model. The bottom of the tray is a perforated material; the hole diameter is 3 mm—material from stainless steel 316. The two upper trays are filled with activated carbon in bulk granules measuring 6-8 mm and filled with activated carbon in a 200 mm thick tray. The bottom tray is emptied and equalizes the distribution pressure of the emission gas flow from the production process unit into the activated carbon filter media. In addition, the gas can be absorbed maximally so that the chimney no longer smells. The distance between the trays is 300 mm with the dimensions of the tray P. 2430 mm, L.1815 mm, T.600 mm, the diameter of the perforated tray.
is 3 mm. The emission gas flow from the production process unit to the dry adsorber unit has a 200-300 m$^3$/minute flow rate and exits through the chimney. The sampling holes are located in the ducting before and after the dry adsorber. The feed mill industry, which will be the pilot project, has a 20-25 tons/hour production capacity. This industry operates in 2 production shifts (16 hours).

2.4 Experimental procedure
The construction and trial stages are carried out after the dry filtration equipment design is completed. There are (two) units of feed mill production machine tools, namely machine unit 1 (M1) and machine unit 2 (M2), both of which have the same type. Both were used as research pilot projects, each with a dry filtration device installed to remove ammonia gas formed from the production process, which was emitted in the flue gas.

The equipment performance test is conducted for 5 (five) months. The first month for preparation and characterization, the next 4 months for observation of the removal process.

The observed variable is the contact time between ammonia gas and activated carbon to achieve maximum ammonia removal efficiency and saturation time.

Saturation time is the performance time of activated carbon required from being active until it is no longer active. It is characterized by the concentration of the adsorbate gas input equal to the concentration of the adsorbate gas output.

3. Results and discussion

3.1. Emission test results from two units of feed mill machines (M1 and M2)
The analysis results of emission sources in the production process unit are needed to determine the concentration of ammonia gas emissions that cause odors, especially from the mixing and conditioning process unit. This will be the basis for the design of the dry filtration activated carbon. The analysis was carried out on emission sources from the M1 and M2 production engine units. The results of the analysis are mentions in table 1.

### Table 1. Emission test results from machine m1 and machine M2.

| Parameter          | Unit    | M1     | M2     | Standards |
|--------------------|---------|--------|--------|-----------|
| Kadar Air          | % vol   | 40.77  | 41.66  | -         |
| Ammonia (NH$_3$)   | mg/Nm$^3$ | 3.979  | 6.918  | 0.5       |
| Hydrogen Sulfide (H$_2$S) | mg/Nm$^3$ | <7     | <7     | 35        |
| Flow rate          | m$^3$/min | 245.5  | 272.0  | -         |
| Temperatur         | °C      | 60     | 57     | -         |

Source: BBTPPI Laboratory, 2020

From Table 2 above, Ammonia emission gas levels from engine 1 and engine 2 exceeded the quality standard of 0.5 mg/Nm$^3$ [6]. This must be controlled and eliminated because ammonia is a dangerous and toxic gas [7].

The water content in the emission gas is also relatively high, and the temperature of the emission gas is also relatively high; this will affect the solubility of ammonia in the emission gas system so that ammonium hydroxide is formed, which raises the pH to alkaline so that it can form a scale and raise the ammonia content to a higher emissions level.

3.2. The design of dry filtration with activated carbon
The design of dry filtration chosen is prioritized to save space and materials, shown in figure 1.
The design of the dry filtration unit for the M1 machine and the M2 machine is designed to be compactly integrated to save place and metal materials. According to the method, the specification of the material used is stainless 316, with a thickness of 3 mm. With dimensions as shown in Figure 2 above: Combined front width (DF-M1 and DF-M2): 3630 mm; DF side length: 2430 mm; DF Height: 5900 mm; the diameter of the intake and output gas emission holes is 700 mm. The interior of DF-M1 and DF-M2 is divided into 3 (three) trays, with a perforated tray bottom with a hole diameter of 3 mm. The distance between the trays is 300 mm with the dimensions of the tray length: 2430 mm, width: 1815 mm, height: 600 mm. As the filter media, activated carbon is used, inserted in tray 1 and tray 2, each with a height of 200 mm. Activated carbon weight 1782 kg. Specifications of activated carbon used: in the form of granules with dimensions of 6-8 mm, loss on heating at 250°C: 7.24% wt, iodine number 956.63 mg/g, ash content 2.29% wt, bulk density 2.02 g/ml, pH 8.64, moisture content 2.69% wt, hardness 2.07% wt, acid solubility 2.07% wt and methylene blue absorption content 62.67 ml/g [12].
3.3. Dry filtration activated carbon construction.

Figure 2. Activated carbon is used to filter media.

Figure 3. Dry filtration construction device.

Figure 3 shows the dry filtration construction device with activated carbon media. This equipment is installed in the industrial feed mill. It can be seen that the input and output pipes carry emission gases from the mixing and conditioning process unit into the dry activated carbon filter from below and then exits through the top to the chimney. Activated carbon is inserted into 2 trays with a thickness of 200 mm in the main unit box, while the bottom 1 tray is emptied. Furthermore, a dry Filtration performance process trial was carried out with a working principle mechanism based on Freundlih's adsorption [11].

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F_{in} \frac{C_{in}}{F_{out}} \frac{C_{out}}{d(W)} = \frac{d(q.W)}{dt}
\]

Where, \(F_{in}\) = inlet gas flow rate (m\(^3\)/min); \(C_{in}\) = inlet gas concentration (mg/Nm\(^3\)); \(F_{out}\) = outlet gas flow rate (m\(^3\)/min); \(C_{out}\) = concentration of outlet gas (mg/Nm\(^3\)); \(q\) = the amount of gas adsorbed/amount of adsorbent (mg/kg); and \(W\) = weight of adsorbent (kg).
3.4. Trial result of dry filtration with filter activated carbon

![Filter Machine 1](image1)

**Figure 4.** Contact time affects the efficiency of ammonia adsorption on machine 1.

![Ammonia Adsorption Rate on Machine 1](image2)

**Figure 5.** Ammonia adsorption flow against activated carbon per minute on machine 1.

Using the dry adsorption method with an activated carbon filter, Ammonia removal was chosen because it does not leave secondary waste and can be regenerated when the filter is saturated. It can be recycled and reused so it can be environmentally friendly [9]. In the operation of feed mill machines, during testing, both Engine1 and Machine2, emission ammonia sampling was carried out at the input and output of the dry filtration unit periodically every 2 (two) weeks for 4 (four) months of production. In Figure 5 (M1-DF1), it can be seen that the first sampling showed a high ammonia adsorption efficiency reaching 94.40% with the highest concentration of 3,979 mg/Nm$^3$ until finally in the 8 times sampling, the absorption efficiency decreased still around 81.96%. This decrease is due to the activated carbon adsorption capacity has begun to decrease [13].

The decrease in the concentration of ammonia to 0.173 mg/Nm3 and has met the quality standard. The absorption efficiency is still around 82%, with a contact time of about 5 months. This shows an indication that the activated carbon does not need to be replaced. The activated carbon replacement will
only be carried out if the input ammonia level is almost the same as the output ammonia level, meaning that the adsorption power is meager and the absorption efficiency is close to 5%. Figure 6 explains that in calculating the adsorption power of activated carbon according to Freundlich's law per mg of adsorbate per unit time per kg of adsorbent, it is per mg of ammonia per minute per kg of activated carbon, is calculated at each sampling. As shown in figure 6, starting from the first sampling to the 8th sampling, the trend continues to decline. This is because the adsorbate has entered the pore group of the adsorbent from the start, which causes the surface pores to close more and more, thereby reducing the adsorption power of activated carbon [13]. It was shown that in the first sampling of M1, the adsorption power of activated carbon was 0.471 mg ammonia/minute/kg activated carbon. At the 8th sampling, after 4 months, the adsorption power decreased to 0.012 mg ammonia/minute/kg activated carbon.

![Figure 6. Contact time affects the efficiency of ammonia adsorption in machine 2.](image)

![Figure 7. Adsorption ammonia flow against activated carbon per minute on machine 2.](image)
Figure 7 above, machine M2 shows that the absorption efficiency in the first sampling reached 95.01%; it was seen that the efficiency trend continued to decline in the following sampling until the 8th sampling in 4 months of dry filtration operation decreased to 68.23%. Based on Freundlich's law, this indicates a decrease in the adsorption power of activated carbon [13].

However, the saturation time of the activated carbon adsorbent has not yet been reached because the concentration of the input ammonia is still far different from the output ammonia adsorbate. The low efficiency on the 8th side was because, at that time, the input ammonia concentration was relatively high, which was due to a change in the product type formula that affected the high concentration of ammonia emissions, so that the output ammonia concentration was still above the required quality standard of 0.5 mg/ammonia. In figure 8, starting from the first sampling to the 8th sampling, the trend continues to decline. This is because, from the start, the adsorbate is still easy to enter the pores of the activated carbon adsorbent, which can cause the surface holes of the adsorbent pores to be closed, causing the adsorption power to decrease [13]. This is shown in the first sampling of M2 activated carbon adsorption power of 0.586 mg ammonia/minute/kg activated carbon. At the 8th sampling, after 4 months, the adsorption power decreased to 0.084 mg ammonia/minute/kg activated carbon.

4. Conclusion
The following have been achieved: the application of the dry filtration design with activated carbon filter media to eliminate the ammonia odor in the feed mill factory. For the M1-DF1 engine, the activated carbon absorption efficiency ranges from 81.96% - 94.40%, with an initial activated carbon absorption capacity of 0.471 mg ammonia/minute/kg activated carbon. After 4 months of operation, the absorption of activated carbon decreased to 0.012 mg ammonia/minute/kg activated carbon. The performance results of the M1-DF1 engine in every first sampling up to 8 for the M1 engine meet the quality standards. Saturation time has not been reached, will be reached more than 4 months. For the M2-DF2 engine, the carbon absorption efficiency ranges from 79.73% – 95.01%, with an initial carbon absorption capacity of 0.586 mg ammonia/minute/kg activated carbon. After 4 months of operation, the absorption of activated carbon decreased to 0.084 mg ammonia/minute/kg activated carbon. Saturation time has not been reached, will be reached more than 4 months. The results of the performance of the M2-DF2 machine in every first sampling up to 7 for the M2-DF2 machine meet the quality standards. Sampling for 8 outputs did not meet the quality standards because there was a change in feed formulation. This technology is feasible to control ammonia as an odor pollutant in the feed mill industry.

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