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Diagnosis of air quality in broilers production facilities in hot climates

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Abstract. The objective of this study was to evaluate air quality of industrial farms of broilers production, located at Zona da Mata region, Minas Gerais, Brazil. The environmental air quality was evaluated during the last rearing week, between 35 and 42 days of life of broilers. Facilities with beds constituted by two types of substrates were evaluated: coffee husks (6 reuse cycles) and shavings (4 reuse cycles). A total of 30 facilities (3 per each of the 10 reuse cycles) were investigated. Air quality was diagnosed by determining air temperature and relative humidity and by ammonia and carbon dioxide concentrations. Air temperature and relative humidity were not affected by reuse cycles in coffee husks bed, but these variables were affected by reuse cycles in shavings bed. Ammonia and carbon dioxide concentrations increased linearly according to the reuse cycles for both types of bed. The maximum concentrations of ammonia and carbon dioxide were 25 ppm and 1,348 ppm in facilities with bedding of coffee husks and 10 ppm and 1,075 ppm in facilities with bedding of shavings, respectively. Air quality of facilities using coffee husk bed tends to be worse when compared to facilities using shavings bed due to the higher values of ammonia and carbon dioxide concentrations, as observed in this study. In conclusion, regardless bedding type, increases in reuse cycles tend to decrease air quality inside the facility, since a linear increasing in ammonia and carbon dioxide concentrations can be observed in relation to the number of bed reuse cycles.

Key words: air pollutants, air quality, gas concentration, livestock, poultry.

INTRODUCTION

Brazil is the second largest producer and the world's largest exporter of chicken meat, with 12.9 million tons produced in 2016 (ABPA, 2017). This intensive production combined with increased production of waste in the facility can cause significant impacts on soil, water and air (Calvet et al., 2011).

Air quality is one of the most important factors in poultry production (Menegali et al., 2009), since air pollutants, possibly present in aviaries, can alter the ideal characteristics of the air. Therefore, respiratory diseases may occur in animals and people, besides damages in the production system by negative effects on animal performance (Alencar et al., 2004; Nääs et al., 2007).

Ammonia is an air pollutant that is frequently found in high concentrations in aviaries (Owada et al., 2007). In broilers production facilities, ammonia is generated during the microbial decomposition processes of wastes that are deposited in the avian bedding. This process is influenced by air temperature, air humidity and pH of waste (Manno et al., 2011; Marín et al., 2015; Cemek et al., 2016). When the ammonium ion (NH_4^+) present in waste is converted to ammonia (NH_3), volatilization of ammonia occurs to the environment (Oliveira & Monteiro, 2013). On the other hand, the ammonium ion (NH_4^+) by nitrification and denitrification processes can be converted to nitrous oxide (N_2O), an important greenhouse gas (Felix & Cardoso, 2004; Marques, 1992).

The carbon dioxide production in animal production facilities is related to animal metabolism (CIGR, 1994), which, in turn, is affected by air temperature and relative humidity (Calvet et al., 2011). Under normal conditions carbon dioxide presents concentration from 500 to 3,000 ppm in animal production facilities, which may represent a health risk and affect animal production performance (CIGR, 1994).

Considering its impacts on the environment, more than a decade ago, the emissions of polluting gases were the focus of studies of researchers in several countries of Europe and North America (Scholtens et al., 2004; Mosquera et al., 2005; Faulkner & Shaw, 2008). In these regions, there are inventories that allow the establishment of protocols for gases emission reduction. For these countries, the determination of emissions in the structures is relatively simple, since most of the facilities are closed and, therefore, have an adequate control on the volume of air.

However, for regions of tropical and subtropical climates, such as Brazil, the determination of these emissions are much more complex (Mendes et al., 2014). In fact in Brazil almost all animal production facilities are kept open for most part of time (Tinôco, 2001). Therefore, in such situations it is difficult to determine gases emissions (Saraz et al., 2013). The same condition is observed for hybrid systems, where installations can remain open or closed, according to environmental thermal variables. This is the case of positive ventilation systems which are open-side facilities that rely on fans to control the internal thermal environment (Manno et al., 2011).

The climatic conditions of warm climate countries allow animal production in open facilities, and thus, provide ideal conditions for the practice of reusing the avian bed (Marín et al., 2015). This practice has become a reality in Brazil mainly due to the impossibility of using avian bed in ruminant feeding (Brasil, 2001) and also due to the difficulty of acquiring new substrates. The avian bed reuse allows the reduction of waste generated, and thus, contributes to minimize the environmental impacts (Vieira et al., 2015). For hot climate regions there are few studies and methods to determine the emission of polluting gases (Mendes et al., 2014). In addition, studies related to air quality in livestock production are still limited to some initiatives related to animal and worker health or odours problems close to the facilities.

Knowledge of gas emission levels is a major guiding factor for national and international regulatory agencies to exercise environmental control and eliminate barriers in the commercialization of products in the poultry production (Osorio-Saraz et al., 2014). As well as maintaining the position of the largest exporter of chicken meat, Brazil must comply with international standards and requirements, taking into account the required quality standards, animal welfare requirements and environmental issues related mainly to air quality.

Consequently, research is needed in the area with the aim to identify and quantify pollutants in facilities, and then to adopt systems for the mitigation of environmental impacts. It will allow to improve the quality of the production environment due to lower emission of gases with greenhouse potential for the planet, aiming sustainability of production by preserving the environment for future generations (Marín et al., 2015).

Therefore, given the need of air quality monitoring in animal production environments in hot weather conditions, that is the reality of Brazil, this study was carried out aiming to make the diagnosis of air quality. The diagnosis was based on air temperature and relative humidity, and ammonia and carbon dioxide concentrations in industrial broiler production facilities commonly adopted in hot climate countries, i.e. predominantly open facilities.

MATERIALS AND METHODS

This study was conducted in farms for broilers production, located in the region of Zona da Mata of Minas Gerais, Brazil (Fig. 1). The poultry facilities were subjected to similar climatic conditions. The climate of this region according to the Köppen classification, is the type Cwb - tropical climate of altitude, with rainy summer and mild temperatures.

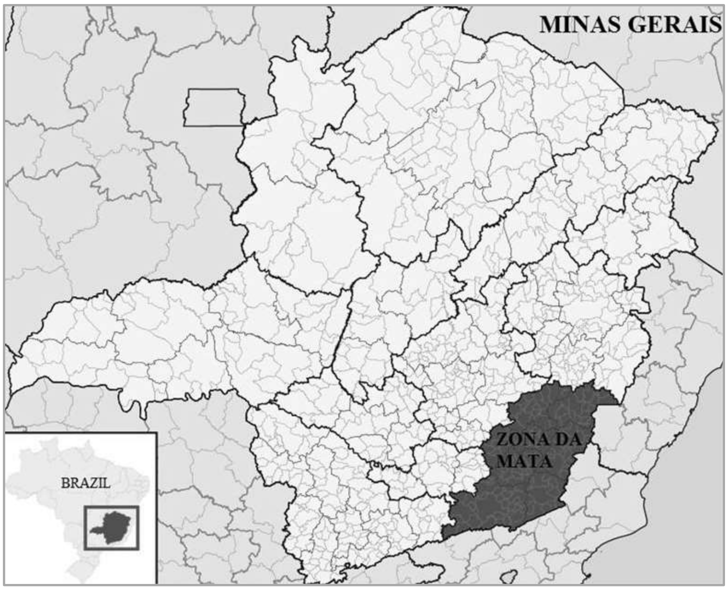

Figure 1. Location of the Zona da Mata, Minas Gerais, Brazil.

All facilities had the same construction typologies, representative of the poultry industry of Minas Gerais state and Brazil, typical of the patterns adopted in hot countries. The constructional features were the same; orientation East-West, width between 12 and 14 m, height in the eaves from 2.8 to 3.2 m, length greater than 100 m, walls of 20 cm on the sides and closure with screens and curtains. The facilities had automatic feeders and drinkers. They remained predominantly open and had a positive pressure ventilation system with axial fans arranged on the sides, activated according to the necessity of internal temperature control, especially in the final phase of breeding and in very hot days (Fig. 2, A and B).

A layer of bedding was kept on the floor (approximately 10 cm depth) and the stocking density was maintained between 14 and 18 birds per m^2. The animals were Cobb males. The birds were fed with the same feed, made using the ideal protein concept, which is widely used for the broiler production industry (Campos et al., 2012).

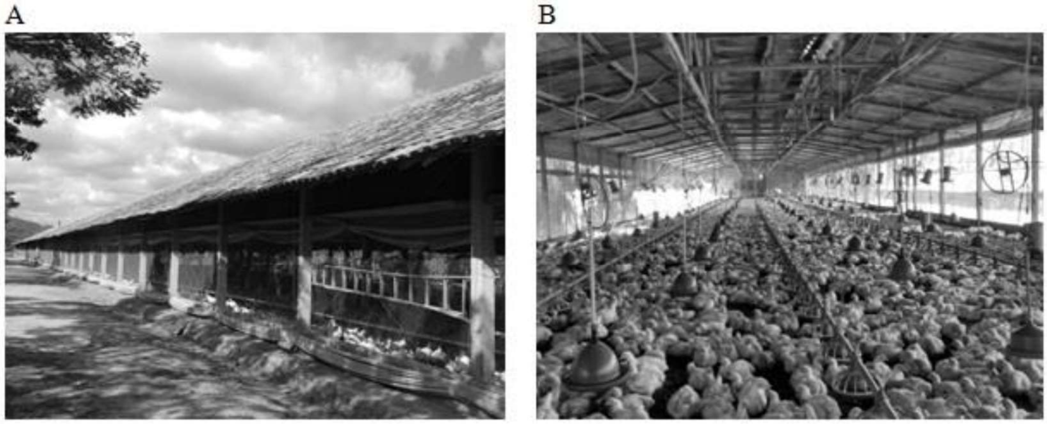

Figure 2. External (A) and internal (B) view of one of the evaluated facilities.

The air quality was evaluated in facilities that had different types of substrate in the bed (coffee husks and shavings) with different numbers of reuse cycles (up to 6 cycles for coffee husks and up to 4 cycles for shavings). These materials are commonly used in the mentioned regions, due to the great availability and low cost. A total of 10 different avian beds were analysed: 4 shavings beds (from 1st to 4th reuse cycle) and 6 coffee husks bed (1st to 6th reuse cycle). For each of these 10 types of avian beds, 3 facilities containing the same type of bed in the same reuse cycle were analysed, totalling 30 investigated aviaries.

The diagnosis of air quality was performed by determining the instantaneous air temperature and relative humidity, and ammonia and carbon dioxide concentrations. The data were measured during the last week of rearing, between 35 and 42 days of life of the chickens, in order to obtain homogeneous samples, representative of each case and to ensure the presence of the largest possible waste load in bedding, i.e. the maximum potential situation of greenhouse gas emissions.

The data of air temperature and humidity were obtained with use of data loggers HOBO U14-002 (Onset Computer Corp.) with a resolution of 0.02 °C and 0.05%, accuracy ± 0.21 °C ± 2.5% and range measurement from - 20 to + 50 °C and 0 to 100%. The carbon dioxide concentration was measured by a CO_2 sensor with a resolution of

1 ppm, accuracy of ± 30 ppm (± 5% of reading) and measurement range from 0 to 5,000 ppm. The ammonia concentration was determined using an electrochemical ammonia detector 'Gas Alert Extreme NH_3' (Honeywell / BW Technologies) with 1 ppm resolution, measuring range from 0 to 100 ppm, properly calibrated before data collection using a calibration gas standard (White Martins®).

The experiment was conducted in a completely randomized design, in which the effects of different reuse cycles of coffee husks and shavings beds were evaluated. All analyses were performed by analysis of variance (ANOVA), using the MIXED procedure of SAS (SAS Institute Inc., 2008), according to the model presented in Eq. 1:

$$Y_{ij} = \mu + T_i + \varepsilon_{ij} \qquad (1)$$

where Y_{ij} – dependent variable; μ – overall constant; T_i – treatment effect (reuse cycles); ε_{ij} – random error.

Due to the different number of reuse cycles obtained for coffee husks (6 cycles) and shavings (4 cycles), the ANOVA was conducted separately for each type of bed. The effect of bed cycles was evaluated by the orthogonal decomposition of the fixed effect of treatment into linear, quadratic and cubic effects. The denominator of degree of freedom was estimated using the Kenward-Roger approximation, and significant differences were declared when $P < 0.05$.

RESULTS AND DISCUSSION

Coffee husks bed

From the descriptive data referring to the facilities using coffee husks bed, it is evident that the experiment was carried out under different climatic conditions, due to the difference between maximum and minimum values of air temperature and relative humidity (Table 1). It was observed that there was more than 10 °C of difference between minimum (18.4 °C) and maximum (28.8 °C) temperatures and 35% of difference between the extreme values of relative humidity, ranging from 43 to 78%.

The maximum ammonia concentration was 25 ppm. This value exceeds the maximum recommended for both people and animals. The health tolerance limit set by the Brazilian regulatory standard NR-15 (Brasil, 1978) for operations and unhealthy activities of workers exposed to these contaminants is 20 ppm. On the other hand, the recommended limit for ammonia that does not affect animal performance in the facility is 10 ppm (CIGR, 1994).

Table 1. Descriptive data for bed of coffee husks

Variable	*n*	Avg.	Std.	Min.	Max
Air temperature (°C)	18	24.8	27.6	18.4	28.8
Air relative humidity (%)	18	58.83	8.27	43.00	78.00
Ammonia (ppm)	18	12.44	6.71	4.00	25.00
Carbon dioxide (ppm)	18	974.94	194.01	662.00	1,348.00

The carbon dioxide concentration ranged from 662 to 1,348 ppm. The maximum value observed in this study is lower than the limits established for animal and human exposure. Carbon dioxide concentration up to 3,000 ppm does not affect the health and performance of animals (CIGR, 1994) and the concentration of 3,900 ppm is defined as the limit of tolerance for health exposure of workers, established by the NR-15 (Brasil, 1978).

As expected, air temperature and relative humidity were not affected by the number of reuse cycles of coffee husks bed (Table 2). These values were related to external local climatic conditions at the time of data collection, since the facilities remained open during the experimental period that was carried out in the last week of rearing of broilers, when the temperature of thermal comfort is in the range of 21 and 23 °C (Macari, 1996). According to the averages in the different reuse cycles it is observed that despite the use of positive pressure ventilation systems as a way of lowering the air temperature, almost all the installations were in a condition of thermal discomfort by heat.

The average values of ammonia and carbon dioxide concentrations increased linearly ($P < 0.05$) as bed reuse cycle increased (Table 2). The highest averages occur in the largest numbers of reuse cycles.

Table 2. Average values of air temperature (T), air relative humidity (RH), ammonia (NH_3) and carbon dioxide (CO_2) concentrations in facilities using coffee husks bed in the different reuse cycles

Variable	Reuse cycles						*P-valor*		
	1	2	3	4	5	6	Lin.	Quad.	Cub.
T (ºC)	24.3	23.8	26.7	26.0	21.7	26.1	0.895	0.803	0.247
RH (%)	58.00	59.33	54.33	54.33	68.00	59.00	0.455	0.619	0.421
NH_3 (ppm)	5.66	8.33	8.00	13.00	15.67	24.00	**<0.001***	0.111	0.337
CO_2 (ppm)	876.67	771.33	1,067.00	845.33	1,136.00	1,153.33	**0.011***	0.507	0.833

* Significant ($P < 0.05$).

In general, the patterns of ammonia and carbon dioxide concentration were similar, increasing due to the increase in the number of reuse cycles (Fig. 3).

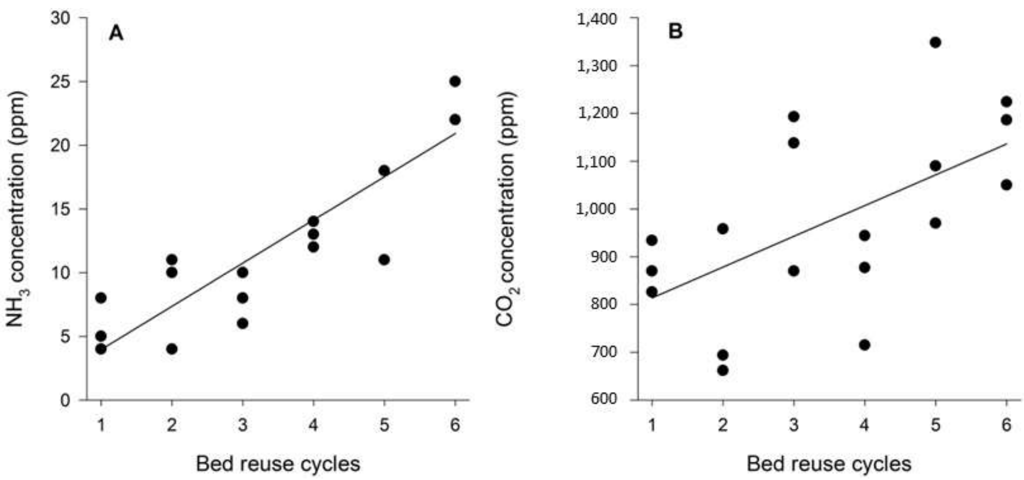

Figure 3. Pattern of ammonia (A) and carbon dioxide (B) concentrations as a function of reuse cycle of coffee husk bed.

The generation and emission of ammonia in wastes are influenced by air temperature and relative humidity (Popescu et al., 2010; Arcidiacono et al., 2015; Cemek et al., 2016), because these factors are able to directly influence the temperature and humidity of the bed, thus favouring the microbial activity in the waste (Manno et al., 2011). According to several studies (Webb & Misselbrook, 2004; Zhang et al., 2005; Furlan, 2006; Furtado et al., 2006; Fabbri et al., 2007; Van der Stelt et al., 2007; Ndegwa et al., 2008; Carvalho et al., 2009; Osório et al., 2009; Rong et al., 2009; Vitorasso & Pereira, 2009; França et al., 2014; Mendes et al., 2014) there is a relationship between air temperature and ammonia concentration in animal production environments, in the presence of waste. In situations of high temperatures (around 35 °C) the microbial activity is intensified, allowing a higher rate of uric acid mineralization, which induces the increase of the potential of both generation and emission of ammonia (França & Tinôco, 2014).

Shavings bed

By the descriptive data of facilities that used shavings bed (Table 3), it can be observed that the data collections were carried out under similar climatic conditions, since there was a difference of only 3.5 °C between minimum and maximum air temperature. However, the relative humidity ranged from 37 to 76%. The maximum ammonia concentration was 10 ppm and the carbon dioxide concentration varied between 726 and 1,075 ppm.

The maximum values of ammonia (10 ppm) and carbon dioxide (1,075 ppm) were within the exposure limits recommended for animals and people. As previously mentioned, in animal production facilities, the limit for ammonia concentration is 10 ppm (for animal) and 20 ppm (for people) and carbon dioxide concentration for animals and humans is 3,000 and 3,900 ppm, respectively (Brasil, 1978; CIGR, 1994).

Table 3. Descriptive data for shavings bed

Variable	*n*	Avg.	Std.	Min.	Max
Air temperature (°C)	12	27.6	1.37	25.8	29.3
Air relative humidity (%)	12	52.58	12.25	37.00	76.00
Ammonia (ppm)	12	5.63	2.65	2.00	10.00
Carbon dioxide (ppm)	12	891.83	99.61	726.00	1,075.00

The air temperature was linearly affected by reuse cycles, while air relative humidity presented a cubic effect of reuse cycles (Table 4). However, as the facilities were predominantly open during the data collection period, the effects observed for temperature and relative humidity appear to be more related to environmental variations than to the effect of the reuse cycles. From the average values of temperatures, it was observed that the facilities with bed of shavings were in condition of thermal discomfort by heat, with temperatures above 25 °C while the thermal comfort range for broilers in the last week of breeding is in the range between 21 and 23 °C (Macari, 1996).

The average values of ammonia and carbon dioxide concentrations of shavings bed increased linearly ($P < 0.05$) as the reuse cycles increased (Table 4). The highest average values of ammonia and carbon dioxide were observed for the highest number of reuse cycles.

Table 4. Average values of air temperature (T), air relative humidity (RH), ammonia (NH_3) and carbon dioxide (CO_2) concentrations in facilities using shavings bed in the different reuse cycles

Variable	Reuse cycles				*P-valor*		
	1	2	3	4	Lin.	Quad.	Cub.
T (°C)	25.9	28.7	28.0	28.5	**0.046***	0,125	0.105
RH (%)	57.67	41.00	66.00	45.67	0.746	0.818	**0.002***
NH_3 (ppm)	3.67	5.50	4.33	9.00	**0.019***	0.184	0.108
CO_2 (ppm)	789.00	909.67	969.33	999.33	**0.044***	0.071	0.763

*Significant ($P < 0.05$).

In general, ammonia and carbon dioxide concentrations increased as the reuse cycle increased (Fig. 4), presenting similar pattern as observed for coffee husks bed and previously discussed.

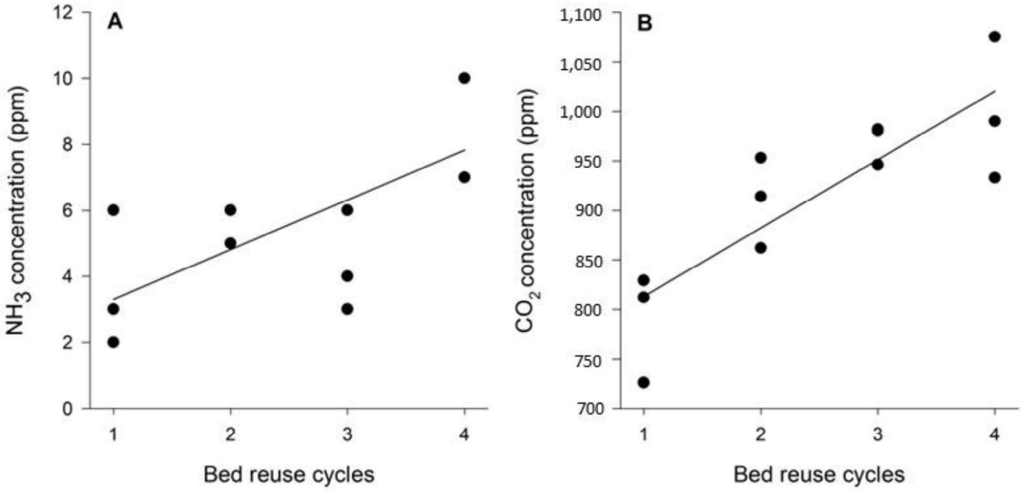

Figure 4. Pattern of ammonia (A) and carbon dioxide (B) concentrations as a function of reuse cycle of shavings bed.

Comparing the two types of bedding (coffee husks and shavings), from the first to the fourth reuse cycle, it is observed that in general the values of ammonia concentration in the facilities with coffee husks bed were higher than the values found in the facilities with shavings bed. The same pattern is observed for the carbon dioxide concentration values. By the general pattern of the carbon dioxide concentration values, for both the shavings and coffee husks beds, an increasing linear pattern of the carbon dioxide concentration with the increase in the number of bed reuse cycles is remarked.

The environmental air conditions influence the characteristics of the avian bed, as the air temperature increases the beds become dryer (Tasistro et al., 2008; Oliveira & Monteiro, 2013). The moisture content of the bed influences the ammonia volatilization, which increases with the increase of moisture. According to data obtained in this study, before the first use the shavings have a moisture content of 7%, while the coffee husks have a moisture content of 15%. This higher moisture content of coffee husks may give greater ammonia volatilization and consequently provides an environment with higher ammonia concentration. On the other hand, the pH values obtained in this study for the shavings were around 4.0 and for the coffee husks were around 5.0. As the pH values of both materials before the first use are quite similar, the factor that has greater influence on the final bed pH is manure that is deposited in the avian bed over the reuse cycles. Therefore, the increase in the number of bed reuse cycles causes increases in the ammonia concentration in the environmental air of the aviaries. As conclusion, in facilities with coffee husks bed the air quality tends to be worse when compared to the facilities with shavings bed.

Regardless bedding type, it is observed that the increase in the number of reuse cycles tends to decrease air quality due to the linear increase in ammonia and carbon dioxide concentrations. Similar results were reported by Pereira & Mesquita (1992); Oliveira et al. (2003); Miles et al. (2011); Marín et al. (2015). They evaluated the beds of wood chips and coffee husks with up to four reuse cycles and concluded that the increase in the number of reuse resulted in higher ammonia emissions.

CONCLUSIONS

The study allows to draw some conclusions. In particular, in relation to the type of bedding, it has been remarked that facilities using coffee husks bed tend to have poorer air quality when compared to facilities using shavings bed, due to the higher values of ammonia and carbon dioxide concentrations.

Regardless of the reuse of the bedding, the increase in the number of cycles tend to worsen air quality inside the facility, as shown by the linear patterns of ammonia and carbon dioxide concentrations values in relation to the number of bed reuse.

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