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Review

Mitigating Air Pollution from Poultry Farming in Brazil: Insights and Solutions for a Cleaner Environment

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The Brazilian broiler industry is the most prominent branch in farming, due to its high levels of productivity. However, there is a growing concern about the environmental damages caused by such an activity, in special the atmospheric air pollution, as a consequence of the high volume of residues generated and the damages made to the environment. Air pollution, despite being most of the time detected by undesirable odoriferous substances, can be caused by numerous atmospheric pollutants such as particulate matter, odorless gases, non-volatile compounds, amongst others. This negatively impacts the health of both humans and animals, as well as of the surrounding ecosystem. Broiler production can be understood as a range of steps necessary to poultry meat production. Hence, their emissions can be computed all the way from the grain production, the feed fabrication, the poultry farming to, finally, the slaughtering and recycling of animal based products. As the poultry chain is well-segmented in its functions, it is necessary to establish and quantify the real impacts caused by its sectors and define mitigation controlling measures in regards to air pollutants.

Key words: Air quality, atmospheric pollutants, control, environment, productivity.

INTRODUCTION

Poultry, in the recent Brazilian economy, had an increase of productivity that is intimately associated to the technological advance and, mostly, to the progress of the industrial sector. However, as in all agricultural activities, this sector generates a large amount of pollutants to the environment, in particular air pollutants (Oliveira and Biazoto, 2012). Poultry production systems generate harmful emissions to the atmospheric air, from food and supply production, such as soybean and corn, for example, to the slaughter industry, prior to the subsequent marketing of the meat. Emissions to the environment range from undesirable odors, due to the concentration of sulfuric gas, ammonia and methane, to the suspension of particulate matter and dust (Meda et al., 2011; Copeland, 2014); the discharge of high volumes of carbon monoxide and carbon dioxide produced during the periods in which heating systems are active, must be considered.

Furthermore, factors such as the improper system management and failures in computing all the balance of the released gases for the manufacturing of the supplies can contribute to the underestimation of the polluting potential of the poultry farms. Therefore, it is necessary to study the real impacts that cause poultry production on the environment. According to Valipour et al. (2012), without the exact information about quantity and quality of pollution sources, reducing or eliminating industrial pollutions are not possible.

Hence, the aim of this review article was to identify the types and means of air pollution associated to the poultry production in Brazil and to list a set of mitigation measures to reduce the impacts caused by their emissions.

AIR POLLUTION IN THE POULTRY CHAIN

Atmospheric pollution can be understood as the air contamination by insertion or temporary maintenance of substances that are normally absent in natural air composition or are present in amounts proportionally superior than the natural (Barrenetxea, 2003). The unpleasant odor is the most sensible form of pollution to humans and becomes a difficult problem to deal with when it concerns a reasonable number of people, intervening in their well-being (Licco, 2002). However, several other pollutants can contaminate the atmospheric air without our perception, as the presence of particulate matter and odorless gases in high concentrations.

Poultry production in Brazil is a well-segmented sector with clearly defined functions throughout its several processes. The impacts related to air quality must be considered in order to determine its potential as a pollutant source and waste generator. All steps that directly or indirectly contribute to the production and/or processing of any supply or natural property that will be subsequently used in the sector can be considered as part of the poultry chain. Therefore, in relation to air quality, the main stages that represent any environmental impact form are these: grain production, feed factories, growing barns, and the slaughtering industry. This article will approach air pollution sources, as well as the proposals and suggestions of mitigation measures of control to reduce the environmental damage caused by the poultry production chain.

AIR POLLUTION FROM THE GRAIN PRODUCTION TO THE FEED MANUFACTURING

Broiler food and feed production is constantly modernizing and increasing its productivity rates. However, the same time, there is a significant contribution to the generation of atmospheric pollutants in the cultivation and management of the cultures utilized in feed manufacturing. Nearly the totality of broiler concentrates in Brazil is formulated from two basic ingredients: corn, a great energy source, and soybean meal, which contributes with high quality proteins and good availability of amino acids (Opalinski et al., 2006). These two foods have high digestibility when compared to other ingredients used in the formulation of broiler feeds (Olukosi et al., 2007). Furthermore, from the nutritional point of view, they complement each other by supplying limiting amino acids, lysine, and methionine essential to growth and protein synthesis of the animal organism, increasing the productivity performance (Bertechini, 2012).

In order to grow maize and soybean, appropriate soil preparation, use of chemical fertilizers and the application of the required agrochemicals are strictly necessary. The environmental impact in due to the mixing and preparation of the soil happens is due to the emission of particulate matter, mainly silt (Huggins et al., 2007; Olson et al., 2014). Emissions of particulate soil is the second largest source of dust, behind the sea salt. When the soil is airborne into the atmosphere, it can be transported to and get in contact with human body. This may result in problems such as eye irritation, respiratory disorders, lung disease, and an increased risk of lung and skin cancers (Sing and Sing, 2010). With concern to the use of chemical fertilizers, it is important to remember that they are derived, mostly, from petroleum and that their production releases undesirable pollutants, such as nitrogen oxides and sulfur dioxides. These products, when applied to the soil in excess can cause environmental adversities, such as acid rain, also in addition to causing dependence on fossil energy mix.

In regards to the agrochemicals applied on cropping systems, there is no doubt that they can damage human health and to the local biodiversity where the farming is located (Silva et al., 2005). This is due to contamination and percolation risks of these compounds, reaching water bodies but also volatilizing to the in atmosphere. Employees working directly with the soil under these conditions are mostly susceptible to respiratory diseases (Pignati et al., 2014). There is also an adverse effect from the contamination and cross-infection in humans due to the consumption of livestock products which are fed with contaminated grains (Fiocruz, 2011). The risks and effects may be even more pronounced due to a higher dispersion of pollutants to natural biomes and also to the usage of inadequate and inappropriate techniques of applying agrochemicals. Amongst the most susceptible segments of the population are the children, who once exposed to contamination may develop of cancer (Curvo et al., 2013).

Growing maize also leads to emission of particulate matter to the environment via pollen, which can cause allergies and predisposition to other respiratory diseases (Solé et al., 2008). It is also important to emphasize that, in air pollution, all damage caused by the emission of a particular air pollutant, be it a gas or particulate matter, depends on the concentration level and exposure time to the contaminant. Therefore, it is possible that certain cultivation techniques applied to extensive monoculture fields will result in a potentially relevant pollutant source in agriculture.

MITIGATION MEASURES OF AIR POLLUTION IN GRAIN FARMING

As controlling measures for pollutant emissions to the air, originated from farming techniques for the production of grains, one example is the appropriate application of fertilizers. With the rational use and the more widespread application of organic fertilizers, along with the adoption of techniques such as direct planting, pollutant and particulate matter emissions can be significantly reduced (Kibblewhite et al., 2008).

Another measure that has been getting more popularity, but that is still very controversial, is the use of transgenic species, which are organisms that present more resistance to plagues and that require relatively smaller amounts of agrochemicals, in addition to yield higher productivity per area (Vallero, 2014). However, there is an urgent need for developing detailed studies on the crossover effect and the permanence time of the agrochemicals in the body of the animals that will consume the processed grain in the feed. In addition, the possibility of changing gene expression regarding the physiological activities, which may be transferred to humans, is still to be evaluated. The principle of labelling transgenic food must be adopted in case of doubt or lack of scientific knowledge about its effects in human health, animal welfare and in the protection of the ecosystems (Nodari and Guerra, 2003).

AIR POLLUTION IN GRAIN FACTORIES

After being harvested, the grains proceed to beneficiation and are then sent to the feed factories. In the case of soybeans, it usually goes through a crushing process for oil extraction and then is toasted. This step is needed because raw soybean has anti-nutritional factors, such as enzymes inhibitors and allergic substances, which may result in an inappropriate use of nutrients by the animals that consume it (Xavier-Filho and Campos, 1989). Corn, in its turn, arrives at processing plant as a whole grain, passes through milling and subsequent crushing to acquire appropriate grading. These processing factors, in addition to improving the food digestibility, increase its nutritional value as well and contribute to the improvement of the homogenization of feed and of the ingredients added to the ration.

However, the processes of crushing, mixing and incorporating others ingredients, such as vitamins, minerals, amino acids, anticoccidials, and growth promoters, among others, emissions of a great amount of particulate matter is involved. During the manufacturing process, some important aspects called are checked, such as dust, the emission of gases and undesirable odors. Even though dust is one of the most present pollutants during the process, it is confined to the internal storage step of crushing and dosing of the ingredients, including the management of silos and sacks of grains and the granular ingredients.

The risks of air pollution in this kind of activity reach mainly factory employees, but also affect those who live in the surrounding area. Main pollutants involve the emissions of gases, particulate matter, and undesirable odors, as well as of course, the solid and liquid wastes, which need to have an appropriate destination in order to avoid environmental contamination. Hence, the adoption of good manufacturing practices with a set of principles, rules and procedures is crucial. These for practices may involve proper food handling, involving the process as a whole and aiming to ensure the production of food that is safe and free of contamination by pathogenic microorganisms, toxins, chemical, and physical products, in addition to reducing the environmental impacts (Pilecco, 2011).

MITIGATION MEASURES OF AIR POLLUTION IN FEED FACTORIES

In the case of the feed factories, several measures can be taken to reduce emissions of air pollutants. One of the most significant is using personal protective equipment (PPE), which is an effective way to guarantee the health and safety of workers (Pilecco et al., 2012). As indispensable examples of PPEs are the use of filter masks and goggles to avoid inhalation of undesirable particles and contact with the eye and the use of appropriate clothing, gloves and footwear to reduce the adherence of these particles onto the skin. After all, the length of the working day of an average of eight hours, and the time of exposure to the pollution generated in factories may be high, which, depending on the concentration of harmful compounds, may represent irreversible damage to health.

Thus, the production management, in this case, must propose some effective measures, with clear objectives and well-defined proposals. Subsequently, the producer will be able to determine, along with the regulatory agencies, if their environmental actions were effective and practice. As an example of measures related to the generated pollutants in animal feed production factories, the following are listed:

i. Smoke, odors and gases: the use of air scrubbers to prevent the release of these pollutants has been suggested.
ii. Dust: can be treated through the adoption of collectors (e.g: bag filter), which work as a cyclones and are usually positioned near the largest dust sources, such as the dosing and the blending rooms. Besides, attention should be paid so that the equipment receives appropriate monitoring and constant maintenance, since it can be the cause of leaks. Another way of avoiding particulate material is the appropriate handling of the sacks, which are usually commercialized or sent to recycling. The use of indoors biofilters combined with mechanical ventilation and exhaust for the renovation and improvement in air quality is also indicated (Nicolai and Lefers, 2006).

Even though the objective is always to get the optimum profits by improving productivity, the measures for controlling and reducing pollutants emissions of whatever form or nature can present themselves as a way of adding value to the products.

AIR POLLUTION IN POULTRY BARNS

Envisioning the increase of productivity, the enforcement of sanitary control, the ease of handling, and the optimized environmental control, the poultry farming has significantly increased in intensity. However, the confined growing of animals, in spite of being very productive, presents some disadvantages in relation to the emission of pollutants which must be discussed and taken into account.

Broilers are usually reared in confined systems, on floors covered with a material of specific characteristics, commonly known as litter. The litter can be composed different materials usually easily acquired in the region, are at a low price rate, having good absorption capability and no risk to the health of the animals. The main used materials are shavings, coffee husks, peanut hulls, rice husks, dry grass, and chopped corncob, among others (Garcia et al., 2012). Due to the usually practiced high stocking densities, the broilers have limited mobility, moving about exclusively for the purpose of feeding and resting. In addition, at the end of the cycle, approximately 2.19 kg in natural matter of waste are produced per animal (Santos and Lucas Jr., 2003). From poultry waste, gases and undesirable odors are released which, when reaching high concentrations, are harmful to the animals, farm workers, and people living nearby.

ATMOSPHERIC POLLUTANTS FROM POULTRY HOUSES

Air pollutants can be classified into dust, smoke, mist, moisture, vapors and gases, and carry biological materials such as pollen, fur and microorganisms (CETESB, 2013). Besides, the exposure time and concentration of pollutants inside poultry houses may be associated with the development of respiratory diseases in birds and humans (Nääs, 2004). The particulate matter emitted by poultry houses may contain pathogenic microorganisms in suspension, such as the virus for New Castle's disease, the avian-influenza virus, *Escherichia coli*, *Salmonela* sp. and campylobacter (Cambra-López et al., 2010).

Thus, it has been demonstrated that dust and microorganisms contribute to the development of respiratory diseases, and their emission levels are mainly related to improper management. Baêta and Souza (2010), mentioned that the dust particle size inside the facilities range between 1 to 150 µm, while its production may reach up to 54 mg/bird/day. Hinz and Like (1998) claimed that the dust concentrations are larger in the winter, since the curtains are usually closed in this period to provide poultry with greater thermal comfort.

As for the gaseous pollutants that can be found inside poultry barns, they are mostly harmful, since they may cause direct harm to the health of humans and animals. When present in high concentrations, they act in the respiratory tract and promote secondary effects with systemic reactions in the organism after their absorption (Kampa and Castanas, 2008). Gases and vapors concentrate in a heterogeneous pattern inside the poultry houses. These pollutants have the tendency of moving both by diffusion and convection, precipitating according to their respective molecular weight (Baêta and Souza, 2010).

The most significant gaseous pollutants in the case of poultry houses are ammonia, carbon dioxide, carbon monoxide, methane and hydrogen sulphide (Barrasa et al., 2012). Out of these gases, ammonia is the main pollutant affecting the health of animals and workers (Menegali et al., 2012). Complications from NH_3 exposure in animal rearing facilities have long been recognized. These include respiratory disease (exposure 200 ppm, Anderson et al., 1964), eye damage (exposure 50 and 75 ppm, Miles et al., 2006), inefficient feed conversion (exposure 100 ppm, Charles and Payne, 1966), and decreased weight gain (exposure 50 and 75 ppm, Miles et al., 2004; exposure 50 ppm). More recently, environmental issues related to gaseous emissions from livestock barns are becoming a concern for the animal production industry (Moore et al., 2011) due to the possibilities of compromising terrestrial bio-diversity, inducing aquatic nutrient enrichment, and deteriorating air quality (Mukhtar et al., 2003; Miles et al., 2013).

Ammonia is water-soluble and lighter than air and, for this reason, can be absorbed by dust particles, litter fragments and through animal mucosa. Lima et al. (2011), claim that the concentrations of ammonia in poultry houses are usually around 20 ppm. The type of ventilation, whether natural or mechanical has an important influence on the dispersion of pollutant gases and air exchange inside Brazilian poultry barns (Mendes et al., 2014). The highest concentration of this gas is in the height of 50 cm, at the level of the birds, forming an undesirable microenvironment as a product of the microbial fermentation of excreta (Ferreira, 2010). When in concentrations higher than tolerable, ammonia causes primarily irritation of the mucous membranes of eyes and respiratory system in birds and later, after falling into the bloodstream, has a toxic effect over the physiological metabolism, leading to a decrease in ration consumption and reduced weight gain, therefore interfering in the well-being and health of the broilers (Kilic and Yaslioglu, 2014). Alencar et al. (2002) proposed that tolerable exposure levels to workers are around 25 ppm for an 8 h working day, but for smaller workloads, it can be up to 35 ppm.

Jones et al. (2013) identified significant ammonia emissions upwind in poultry houses, causing damage and corrosion to the facilities close to them. In long term, emissions lead to a great amount of ammonia in the bodies of water, provoking an effect known as "blooming of the algae" (Wiegand et al., 2011). As a consequence, an excessive development of algae such as the diatomaceous and the cyanobacteria takes place, which are responsible for threats to the human health and to the surrounding environment. Examples of health threats of ingestion of diatomaceous and cyanobacteria are: damages to the neurological system and to the liver, irritation of the skin, allergies, respiratory diseases, and increased mortality of fish and other organisms (CETESB, 2013). Despite all the deleterious consequences of its excessive emissions to the environment, Brazilian legislation does not currently regulates emissions of ammonia nor incentivizes the adoption of effective measures to control its spread.

The acceptable levels for carbon monoxide for animals and humans, in turn, are in the order of 10 and 50 ppm, respectively (Wathes, 1999). These values are for 8 h working days and continuous exposition of the animals during the full production cycle. This pollutant is toxic, odorless and is present in the facilities as a product of incomplete combustion of equipment used for heating in the initial phase of bird lives and also due to improper ventilation (Nääs et al., 2007). Carbon monoxide causes, in birds, intoxication by the cells' inability to carry oxygen, competing with carbon and causing hypoxia with the consequent death of animals that are exposed to elevated concentrations of this gas (WHO, 1999).

Carbon dioxide is naturally present in poultry barns. Its concentrations inside the facilities are affected by the metabolic aspects of the animals and to the biological processes occurring in the microenvironment (Hellickson and Walker, 1983). The combustion of fuel used to heat the air up in the initial phase is another factor that contributes to the air pollution inside the facilities. CO_2 concentrations around 600 to 4000 ppm do not threaten animal health; however, they increase of the respiratory rate, consequently increasing heat production (Alencar et al., 2002). The increased heat production caused by CO_2 accumulation will contribute to decreasing the productive performance. In case of continuous exposure, CO_2 levels of up to 3000 ppm are adopted for birds and 5000 ppm for workers with 8 h working days (Wathes, 1999).

The concentrations of methane and hydrogen sulphide inside the poultry houses are relatively low (Nääs et al., 2007). Their effect is more pronounced at the stage of disposal and improper handling of wastes. This is due the typology of the houses used in Brazil, which are usually open, favoring the air renewal and the dilution of pollutants. However, with the use of mechanically ventilated systems, such as dark houses, in order to increase the productivity, the hydrogen sulfide gas has been shown to be a serious problem. Hydrogen sulfide gas is formed by bacterial reduction of sulfate and the anaerobic decomposition of sulfur-containing organic compounds present in manure under (Arogo et al., 2000). The presence of this pollutant has been responsible for many animal and human deaths (Donham et al., 1982). Tolerable concentrations of hydrogen sulfide for broilers must be less than 2 ppm in the first week of life, and be between 3 and 6 ppm in the 4th and 6th weeks. High levels of this gas, may adversely affect the performance and quality of broiler meat, resulting in economic losses (Wang et al., 2011).

As an effective way to minimize the concentration, the accumulation, and the production of these gases, the company can carry on the proper treatment of residues through composting and anaerobic biodigestion (Kelleher et al., 2002).

MITIGATION MEASURES TO REDUCE AIR POLLUTION IN POULTRY HOUSES

The accumulation of gases inside poultry facilities represents the main factor of air pollution in the production cycle. The causes for decreasing air quality in these houses are not specific. Instead, the cumulative effect of some determinants such as ventilation, stocking density, age, the time of the year, adequate management of wastes and humidity excess. Besides impacting the performance of the animals and the health of workers, these factors affect the air quality of residents adjacent to the polluting sources. Therefore, they may cause discomfort and inconveniences, setting the poultry activity as a villain to the socioeconomic progress of the region where it is installed.

Since the causes of the decrease in air quality are diverse, the main proposals of mitigation measures to reduce the impact caused by its respective factors are listed as follow:

i. Stocking density: the larger the density of the poultry stocking is, the higher the dust formation and particulate material dispersion inside the facility will be. It is recommended that the density be of 12 to 14 broilers/m^2, so the animal activity will not cause excessive dust to become airborne or waste of ration, in addition to easing the maintenance of flock uniformity. Mendes et al. (2012) has demonstrated that lower stocking densities in laying hens also allow for reduced emissions of NH_3, become with fewer birds occupying the same floor area, the manure will dry out faster, leading to reduced microbial activity responsible for ammonia emission. By using larger densities, more attention should be given to the handling and, especially to the air-conditioning equipment and the renewal of air inside the facilities.

ii. Ventilation: the ventilation, positive, negative, lateral or in tunnel, aims to dilute the pollutants inside poultry houses and drag them out of the installation, decreasing the undesirable concentrations of pollutants. It is recommended that the wind speed inside the facilities be between 2.5 to 3.0 m/s.

iii. Air and litter humidity: the air humidity must be in the optimal rate of 50 to 70% in order to ease the dispersion of pollutants and the exchanges of the animals with the environment in case of environmental stress.

iv. Curtains: attention must be given to the adequate handling of curtains, ensuring that they are lowered during the warmest hours of the day and in accordance with the time of the year. Even more attention should be paid during the winter period, where curtains are usually raised in order to favor the thermal comfort of the animals.

v. Use of natural barriers: the use of natural barriers is highly recommended, they include trees and bushes, in order to isolate the farm without impairing the natural ventilation.

vi. Farm isolation: the poultry house, if possible, must be isolated from human inhabited areas.

vii. Adequate handling of dead animals: it is estimated that mortality ranges from 3 to 5% in poultry houses. Dead animals must be handled properly. There are two carcass elimination measures that can be adopted in order to reduce air pollution: the composting of dead animals and the use of septic tanks for disposal. These two measures envision the non-emission of methane and odors. The compost of dead animals mixed with the litter material, can be used as an organic fertilizer.

viii. Control of ammonia emissions and odors: in spite of this sort of control not being currently used in Brazil, according to Mostafa and Buescher (2011), the use of dry filters attached to cyclones in closed poultry houses is a very good alternative to mitigate ammonia emissions. Another option is to treat the emissions through electro-chemical oxidation, by “disnitrifying” ammonia into gaseous dinitrogen by using hyperchlorous acid; however, the cost of this process is high (Bejan et al., 2013). In these mechanisms, the use of biofilters in closed sheds allows the processing of generating harmful gases at the end of the process, carbon dioxide, water, minerals, volatile compounds and microbial biomass (Kafle et al., 2015).

ADEQUATE HANDLING OF POULTRY WASTE AS A MEANS TO REDUCING THE PRODUCTION OF ATMOSPHERIC POLLUTANTS

At the end of the growth out cycle, the producer is left with large volumes of waste, including the litter volume used for the lodging of chicks one day of age until slaughter. The litter contains plant nutrients, such as N, P, K and trace elements, such as Cu, Zn and As, pesticide residues, pharmaceuticals such as coccidiostats, endocrine disruptors and microorganisms (Bolan et al., 2010). Moreover, it may also contain pathogenic viruses such as avian influenza (Reis et al., 2012). This material of heterogeneous composition possesses great pollution potential and produces large quantities of CH_4 and CO_2 during the decomposition process. Therefore, measures and alternatives that reduce this undesirable impact are extremely necessary. The practice of composting and anaerobic biodigestion is becoming more popular and presenting good results in the reduction of pollution impacts. Moreover, composting yields excellent organic fertilizers and useful energy that can be used in the property (Kelleher et al., 2002).

COMPOSTING AS A MITIGATION MEASURE FOR AIR POLLUTION FROM BROILERS WASTE

The composting process is an ancient technique that consists on the biological decomposition of complex organic compounds into simpler molecules, with the mineralization of elements desirable for organic agriculture. It is an aerobic process, in which straw is mixed with the waste until a ratio of carbon:nitrogen of around 25:1 is established; the biological degradation process usually lasts for approximately 90 to 120 days (Fialho et al., 2005). Aerating poultry litter compost is very important because it enables the elimination of salmonella (Bodí et al., 2013). At the end of the process, a nutrient-rich organic fertilizer will remain; which will release carbon dioxide to the environment instead of methane, which is 21 times more harmful to the atmosphere. Despite being a good alternative for the waste treatment and reduction of the pollutant potential of waste, the composting process still has a few disadvantages. A considerable amount of area is required for the disposition of the waste and for the constant inversion of the composted windrows.

ANAEROBIC BIODIGESTION AS A MITIGATION MEASURE OF AIR POLLUTION

The anaerobic biodigestion is a natural biological process in which organic matter is reduced to methane in environments free from oxygen (Chen et al., 2008). It consists of four phases or stages of bacteriological decomposition of organic matter: hydrolytic, acidogenic, acetogenic and methanogenic. Anaerobic biodigestion provides a variety of benefits. The odors are significantly reduced or eliminated; a liquid relatively clean for washing and irrigation is produced; the pathogenic agents are substantially eliminated in the liquid and solid products; and reduced emissions of greenhouse (Burke, 2001).

The biodigestors are yet important to the rural sanitation, since the anaerobic digestion process promotes the reduction of organic load, the reduction of solids and the reduction of pathogenic microorganisms present in the effluents. Besides stimulating the recycling of the organic matter and of the nutrients, they enable the sanitizing of the facilities where animals are raised, promoting the treatment of its waste, reducing incidence of flies and unpleasant odors (Bolan et al., 2010).

AIR POLLUTION IN POULTRY SLAUGHTERHOUSES

Poultry slaughterhouses produce a considerable quantity of odors and of toxic pollutants, such as the emissions from combustion in boilers, which are harmful to the environment and to the adjacent population. This is due to cold stores having a sector that carries out the recycling of the material of animal origin attached in their working plant (Licco, 2002).

The main impacts of slaughterhouses are the residual waters and the toxic effluents generated from the humid transformation of residues. In dry transformation, there is air pollution, by non-condensable gases and vapors such as odors, derived from the recycling processes and from the transformation of matter of animal origin. Miller (1975) notes that the main impact of slaughterhouses is the unpleasant odor derived from the rendering plants. Furthermore, about 80 to 85% of the total energy required in a slaughterhouse is produced by the combustion of fuel in the boilers at the industrial unit (thermal energy – vapor and hot water). The main emitted pollutants are the sulfur oxides, nitrogen oxides and particulate matter (CETESB, 2008).

In Brazil, slaughterhouses with precarious installations and hygiene conditions that do not have a system for treating and final disposal of residues are commonly found; this makes the subject of utmost importance. In addition, the Brazilian meat is exported to various countries that usually demand, amongst other conditions, the treatment of the pollution caused by the activity. Of the total amount of broiler chicken meat produced in the country, about 30% is exported to approximately 142 different countries (ABPA, 2014).

MITIGATING MEASURES FOR THE REDUCTION OF AIR POLLUTION IN POULTRY SLAUGHTERHOUSES

The reduction of odor generating sources in slaughterhouses is reached, mainly by maintaining the hygiene level of the environment, and avoiding the accumulation of unpleasant materials. For the treatment of the odor generating sources, biofilters, air scrubbers and filtration with activated carbon can be used (Seth, 2005). In most cases, an efficient solution is obtained with the combination of various methods (Barros, 2007). Oliveira (1990) and Sinhorini (2013) indicate that the intensity of the odor in the facilities of a rendering plant is directly related to the time elapsed from the slaughter of the animal until the instant of residue processing. Therefore, it can be concluded that the shorter the residues are handled, the smaller the amount of undesirable odor emitted. Another important aspect is the careful selection of the location of the slaughterhouse. When designing the slaughterhouse, areas with superior topography must be prioritized, the dominant wind directions must be observed and attention must be dispensed to the distancing from populated areas (Dias, 1999). Regarding odor reducing strategies, the use of biofilters has shown to decrease emissions of odor caused by hydrogen sulfide by around 95% and about 80% by ammonia. However, one must be able to control humidity (30 to 70%) and temperature (38 to 58°C) of the biofiltration process (Nicolai et al., 2006).

In order to control atmospheric emissions, the following is suggested: the particulate material from the boilers that use wood as fuel must be treated through cyclones, through electrostatic precipitators, through gas scrubbers or bag filters (Ferreira et al., 2002). The boilers that run based on fossil fuel (combustible oils) must have their emissions treated by adsorption in activated carbon, through air scrubbers towers and incineration (Oliveira, 1990; Licco, 2002; FEAM, 2010). Brazilian legislation has set standards and resolutions which established maximum limit of pollutant emissions at national level.

Table 1 lists the major air pollutants emitted by poultry production industry, related to its emission source and the main mitigating control measures aiming at improving air quality and reducing threats. To evaluate the control of emissions and success of mitigating actions to control, some techniques have been used: life cycle assessment (LCA) and environmental flow diagram (EFD). The technique of life cycle assessment aims to understand and evaluate the magnitude and significance of the potential environmental impact of a production system (Goedkoop et al., 2008). The use of LCA practice in the production of broilers is a technique able to infer the polluting capacity of generation system as well as identify their sustainability (Boggia et al., 2010); and can be adopted in poultry production. Environmental flow diagram can also be adopted to assess the impacts of poultry. The EFD is based on the power reference system and process flow diagram for a particular industry sector (Valipour et al., 2013). EFD has been applied in civil and industrial construction quite successfully. Occurs through the use of software by companies in order to encode the pollutant sources in the receiving

Table 1. Main air pollutants emitted by the production of broilers, the major emission sources and mitigation measures for improving air quality and reducing environmental impacts.

Chain steps	Air pollutants	Emission sources	Damages	Mitigating measures
Grain farming	*Particulate matter *Agrochemicals in suspension *Excess pollen	*Inadequate soil management *Excessive application of pesticides and fertilizers	*Health problems *Air pollution, soil and water by pollutants *Uncomfortable	*Rational agricultural practices such as tillage *Precise use of fertilizers and pesticides in crop management
Feed factories	*Particulate matter *Smoke, odors and gases	*Inadequate management of the ingredients	*Health problems *Uncomfortable	*Manpower training *Use of PPE *Gas scrubbers and filter collectors for emissions of harmful gases and dust, respectively.
Production of broiler chickens	*Dust and microorganisms *Ammonia,carbondioxide,carbon monoxide, methane and hydrogen sulphide *Odors	*Inadequate management of waste *Poor ventilation *Generously sized equipment	*Health problems *Uncomfortable *Decreased productivity *Development of disease *Contamination of natural resources	*Proper management of waste (composting and biodigestion) *Good ventilation management practices, humidity and density of animals *Use of biofilters in the case of closed sheds
Poultry slaughterhouse and recycling of animal products	*Dust and odors *NOx e SOx *CO	*Industrial boilers and other recycling processes *Inadequate management of waste	*Health problems *Uncomfortable *Air pollution	*Effective management of animal waste *Biofilters, cyclones, through electrostatic precipitators, through gas scrubbers or bag filters

NOx = nitrogen oxides; Sox = sulfur oxides; CO = carbon monoxide; PPE = personal protective equipment.

environment and then determine the energy optimization solutions and reduce environmental pollutants (Valipour et al., 2013). In this way, it can be used successfully in the poultry industry to mitigate the pollution generated.

FINAL CONSIDERATIONS AND CONCLUSIONS

The decision-markers of the poultry production activity must should be conscious of its pollutant potential and search for alternatives in order to minimize their impacts in the environment. On the other hand, consumer increasingly demands for products that are environmentally correct and safe. The processes of rearing broiler chickens and products of animal origin must have an adequate handling of its residues and implement production alternatives that are less aggressive to health and environment, adjusting the production to the current conditions and environmental laws.

Emissions of pollutants from the poultry industry, starting from the production of grains for the fabrication of rations until the slaughter of the animals is significant. The producer and the processing industries must receive all the support necessary in order to implement handling practices and new technologies to mitigate the impacts caused.

The mitigation of atmospheric pollutants in all the steps of the poultry industry is possible due to the existence of emission control methods that have proven to be effective. The reduction of pollutant emission must be faced as a routine procedure, as a requirement of the productive process and not as an obstacle that can be neglected by the agents of the industry.

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Conflict of Interests

The authors have not declared any conflict of interests.

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