

ISSN 1682-8356
ansinet.org/ijps



INTERNATIONAL JOURNAL OF POULTRY SCIENCE

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308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

Effect of Air Contaminants on Poultry Immunological and Production Performance

E.A. Almuhanha¹, A.S. Ahmed² and Y.M. Al-Yousif²

¹Department of Agricultural Systems Engineering, ²Department of Animal and Fish Production,
College of Agriculture, KFUPM, Saudi Arabia

Abstract: The concentration and particle size distribution of airborne particles and toxic gases in two commercial poultry houses were measured and analyzed. This field study was conducted at Al-Ahsa of Saudi Arabia in order to characterize air contaminants in the mechanically ventilated poultry houses under the climatic conditions of Saudi Arabia. In the mechanically ventilated poultry houses (M.V.), the mean Total Suspended Particle concentration (TSP) was 4.25 and 3.64 mg/m³, respectively, the PM₁₀ concentration (particulate matter with a diameter less than or equal to 10 µm) was 2.26 and 1.79 mg/m³, respectively and the PM_{2.5} concentration (particulate matter with a diameter less than or equal to 2.5 µm) was 0.08 and 0.07 mg/m³ respectively. The TSP values were greater than the suggested threshold values for indoor air contaminants in livestock buildings; however, the PM_{2.5} values of both houses did not exceed the suggested threshold values for indoor air contaminants in livestock buildings. The Geometric Mean Diameter (GMD) based on the mass concentration of particles in both houses was 8.45 and 8.31 µm, respectively. The concentration of NH₃, CO₂, SO₂, NO₂ and H₂S was measured and the results indicated that ammonia was the dominant gas in both houses. Moreover, the majority of gases did not exceed the threshold values. At the M.V. poultry house, the concentration of airborne particles and toxic gases was strongly affected by the barn ventilation rate. The current results suggested that the increase of air contaminants and gases negatively affect the general productive performance and immune response under commercial conditions.

Key words: Broiler, air pollutants, TSP, immune response

INTRODUCTION

Poultry industry continues to expand rapidly in Saudi Arabia. The industry, however, faces significant air quality challenges, including emission of particulate matter (TSP, PM₁₀ and PM_{2.5}), ammonia and other toxic gases. It is widely acknowledged that, in many cases, poultry production is reduced by stress imposed on the poultry by environmental, nutritional, pathological and other factors (Hartung *et al.*, 1998; Ritz *et al.*, 2006).

Air quality inside poultry housing has become a major concern, particularly with regard to poultry health. Environmental concerns and nuisance issues related to poultry housing air emissions are an important issue affecting the poultry industry (Ritz *et al.*, 2006). In the majority of these studies, the concentration of air contaminants such as gases (ammonia and carbon dioxide, dust, airborne microorganisms and toxins) was analyzed; however, particulate matter is one of the primary aerial pollutants from poultry housing facilities (Lim *et al.*, 2003; Visser *et al.*, 2006; Liu *et al.*, 2006; Roumeliotis and Van Heyst, 2007).

Organic dust in poultry housing is composed of non-viable particles generated by feces, litter, feed, feathers (which produces significant amounts of allergen dandruff) and viable particulate matter (also called bioaerosols). Airborne dust is one of the primary means by which disease-causing organisms are spread

throughout poultry housing. Reductions in airborne dust levels are associated with significant reductions in airborne bacteria (Mitchell *et al.*, 2004). Dust characteristics (concentration, number and mass) inside livestock housing vary based on the type of animal, building and environmental conditions. Understanding dust characteristics will lead to the development of optimal methods of dust control (Almuhanha *et al.*, 2008; Almuhanha *et al.*, 2009). Dust concentrations in poultry housing ranges from 0.02 to 81.33 mg/m³ for inhalable dust and 0.01-6.5 mg/m³ for respirable dust (Ellen *et al.*, 2000).

The most prominent air pollutants are odors, gases, dust, microorganisms and toxins (Hartung *et al.*, 1998). These materials are considered to be the principal risk factors for respiratory diseases (Wathes and Randall, 1989). Epidemiological evidence suggests that the health of farmers working in livestock housing may be harmed by regular exposure to air pollutants (Whyte *et al.*, 1993). In broiler housing, approximately 30% of the birds that were rejected at meat inspection possessed lung lesions (Valentin *et al.*, 1988). The effect of the litter type and stocking density of broiler flocks on the ammonia concentration, dust concentration and the performance of broilers was studied by AL Homidan and Robertson (2003), who demonstrated that ammonia and dust production affected the litter type and stock density.

Ammonia (NH_3) is produced as a by-product of the microbial decomposition of organic nitrogen compounds in manure. Nitrogen occurs as unabsorbed nutrients in animal feces and as urea (mammals) or uric acid (poultry) in urine (EPA, 2004a). Concern of the effects of gaseous ammonia on the growth cycle of broilers has been primarily focused on the concentration of ammonia inside broiler housing units because high ammonia concentrations affect bird performance. Moreover, ammonia is an odorant gas and has irritant properties. Namely, at concentrations greater than 0.7 ppm, ammonia has a pungent, acrid odor. Alternatively, concentrations of 50-150 ppm can lead to severe coughing and mucous production (Leduce, 1992). In addition to pulmonary disease, exposure to ammonia leads to eye, sinus and skin irritation (Latenser and Louckton, 2000). Similar to the effects observed in humans, ammonia causes the following conditions in poultry: reduced body weight at ammonia concentrations of 25 ppm, respiratory irritation, predisposition to infectious disease and cornea/conjunctiva inflammation (keratoconjunctivitis) at ammonia concentrations of 50 ppm. On a global scale, animal farming systems emit approximately 20 Tg N/yr as NH_3 (Galloway and Cowling, 2002) to the atmosphere, which comprises 50% of the total NH_3 emissions from terrestrial systems (Van Aardenne *et al.*, 2001).

Hydrogen sulfide (H_2S) is a highly toxic gas that can cause death in humans and livestock when acute levels are generated under certain conditions (Patni and Clarke, 1991). Hydrogen sulfide may also cause adverse health effects (irritation, headache, dizziness) at concentrations as low as 10 ppm (DeBoer and Morrison, 1988). Due to its toxic properties and significant contribution to odor, hydrogen sulfide emissions from known sources (i.e., manure pits, storage tanks) should be closely monitored to prevent accumulation to fatal levels and to evaluate its impact on the environment.

Nitrogen dioxide (NO_2) is a reddish-brown toxic gas that has a characteristic sharp, biting odor and is a prominent air pollutant. The most important sources of NO_2 are internal combustion engines, thermal power stations and pulp mills. Fossil fuel heaters are also sources of NO_2 in poultry houses.

The concentration of carbon dioxide (CO_2) in Earth's atmosphere is approximately 390 ppm (parts per million) by volume as of 2010 (NOAA/ESRL, 2011). In animal housing units, additional carbon dioxide is released from the biological decomposition of manure and the respiration of animals. Carbon dioxide constitutes more than 40% of the air bubbles arising from liquid manures stored under slotted floors, lagoons, or oxidation ditches.

Gases such as carbon dioxide, ammonia and methane may accumulate and reach toxic levels if adequate ventilation is not maintained. These different air

pollutants may cause risk to the health of both chickens and farm workers. Poor environments normally don't cause disease directly but they do reduce the chickens' defenses, making them more susceptible to existing viruses and pathogens (Quarles and Kling, 1974). Aerial ammonia in poultry facilities is usually found to be the most abundant air contaminant.

Ammonia concentration varies depending upon several factors including temperature, humidity, animal density and ventilation rate of the facility. Chickens exposed to ammonia showed reductions in feed consumption feed efficiency, live weight gain and carcass condemnation (Charles and Payne, 1966; Quarles and Kling, 1974; Reece and Lott, 1980). Ammonia in poultry houses of course has been recognized as a problem for many years. Several studies reported that ammonia can reduce bird growth performance (Reece *et al.*, 1981; Miles *et al.*, 2004; Beker *et al.*, 2004) and increase susceptibility to diseases and increase subsequent mortality (Kristensen and Wathes, 2000).

The main objective of the present study was to determine the effects of particulate and gaseous contaminants on commercial broiler production, concerning general production performance and immune response.

MATERIALS AND METHODS

Birds and general performance: Two poultry facilities at a commercial poultry farm in Al-Ahsa, Saudi Arabia were studied. The two houses were differing in their air quality measurements according to a pilot study prior to the current study. A complete broiler production period of five weeks was monitored at the current study. Four hundred chicks at each house were used to evaluate the broiler performance and immune response in this experiment. Chicks were divided into 4 replicates in each house. Both feed and water consumption of all treatments were measured every week to establish each the mean daily feed and water consumptions. Body weight changes were determined by measuring live weight for each bird to the nearest 10 g on a weekly basis starting from week zero of the experiment. Data of weekly body weight were used to calculate the weekly body weight gain and feed conversion rate. Regular farm vaccination program was applied typically for both houses. Serum samples were collected on a weekly basis. The Newcastle Disease (ND) antibody titer was assayed using microtitre Hemagglutination Inhibition (HI) test as described by (OIE, 2009).

Poultry housing facilities: The mechanically ventilated poultry houses were located at a commercial poultry farm in Al-Ahsa, Saudi Arabia and consisted of 16 poultry houses. Field measurements were conducted in house No. 14 and 15. The poultry house (gable-even-span form) was equipped with an evaporative cooling fan-pad

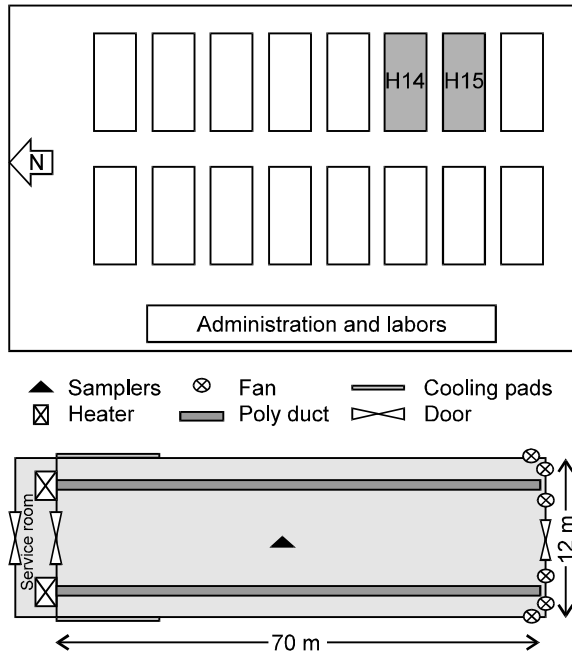


Fig. 1: Schematic diagram of the broiler house equipped with mechanical ventilation (plan view - not drawn to scale)



Fig. 2: Instruments used to characterize aerosol particles inside the poultry houses

system, which was not in operation during the sampling period. As shown in Fig. 2, the geometric characteristics of the house were as follows: eaves height = 4.9 m; gable height = 1.9 m; span angle = 17.6°; total width = 12 m; total length = 70 m; floor surface area = 840 m²; volume = 3,318 m³. The outer and inner surfaces of the side walls were constructed of a metal frame covered by metal sheets and white painted concrete and thermal insulation was placed between the inner and outer surfaces of the walls. The house was equipped with a ventilation system consisting of 3 pairs of extracting fans

(single speed; 1.37 m in diameter; 38,000 m³/h of discharge), which were located on the leeward side of the house and cooling pads were installed on the side toward the prevailing wind. The house was also equipped with two air heaters as a heat source and the hot air distribution system consisted of two perforated plastic ducts located 2.0 m above the floor along the longitudinal direction of the broiler house. The microclimatic conditions of the broiler house were controlled with an automatic controller, which was used to initiate and interrupt heating and cooling and to achieve the required temperature. The broiler house was also equipped with automatic feeding and drinking systems. The house was occupied by 13,000 broiler chickens and the ratio of birds to the total floor surface area was 15.5 bird/m². Sand was used as a bedding material and the sand bedding was mixed weekly and replaced every growing cycle.

Measurement of environmental parameters: The growth cycle of the birds was 35-42 days, beginning at day 1 and extending to the time of slaughter. Conditions within the broiler houses were managed to optimize bird health and productivity. The broiler house was regulated at an initial temperature of 32-35°C and the temperature was reduced by 1°C every second day until a temperature of 24±2°C was achieved at 3 weeks of age. The houses were typically ventilated according to the humidity and temperature. The air exchange rate during the sampling time varied from 0.3-0.5 air exchanges per minute (winter). In the present study, the Ventilation Rate (VR) was measured using a direct measurement method to assess the performance of each ventilation fan. Namely, the time and operating status (ON-OFF) of each fan was recorded. An anemometer (Model Testo 435-2, Testo Inc. 40 White Lake Road Sparta, N.J. 07871 - USA) was used to measure the air velocity traverse along the cross sectional area of the fan (Predicala and Maghirang, 2003). The average velocity was multiplied by the effective cross sectional area to obtain the mean ventilation rate of each fan. The building VR was determined by summing the operating flow rates of each fan (Hong *et al.*, 2009).

The air temperature, relative humidity and carbon dioxide (CO₂) concentration were measured using a multi-functional instrument equipped with an IAQ probe to assess the indoor air quality (Testo 435-2, Testo Inc. 40 White Lake Road Sparta, N.J. 07871 - USA). Measurements were obtained every 30 s and the average values obtained over a 1-min interval were recorded.

Measurement of airborne dust and gaseous contaminants: The following environmental parameters inside the broiler houses were recorded: (1) size distribution of airborne particles; (2) mass and number

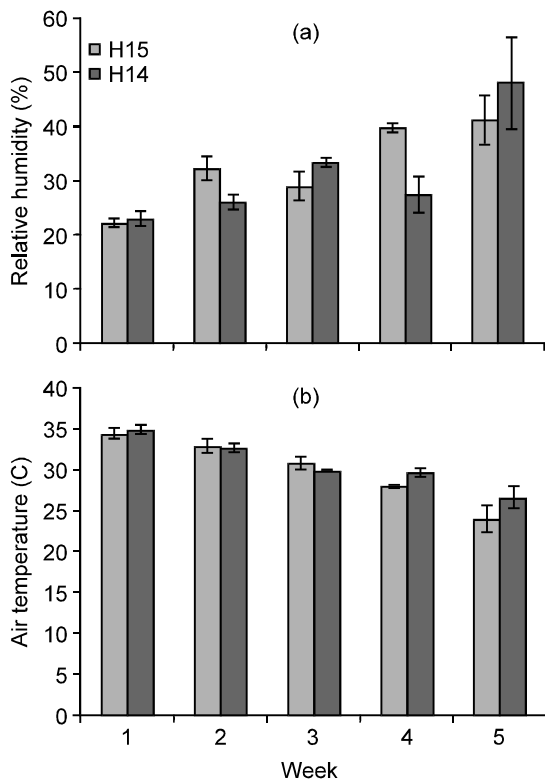


Fig. 3: Changes in the air temperature and relative humidity inside the M.V. broiler house as a function of the growth cycle during the experimental period. (a) relative humidity and (b) air temperature

concentration of airborne particles; (3) concentration of toxic gases. Samplers and/or measurement devices were located at or near the center of the building to obtain a representative measurement of the entire house and to avoid overestimating or underestimating the data, as shown in Fig. 3. The size distribution and number concentration of airborne particles were monitored using a particle counter (Model GW3016A, GrayWolf Sensing Solutions, Advanced Environmental Measurements, 12 Cambridge Drive, Trumbull, CT 06611 USA). The spectrometer measured particles with aerodynamic diameters ranging from 0.3-10 μm at an air sampling rate of 0.1 CFM (2.83 LPM). Moreover, 6 channels were used and a counting efficiency of 50% and 100% was employed for particles with diameters of 0.3 μm and >0.45 μm , respectively. The spectrometer displayed the particle count and mass concentration readings in $\mu\text{g}/\text{m}^3$.

Real-time data and the mass concentration of TSP, PM_{10} and $\text{PM}_{2.5}$ were measured with the aforementioned particle counter (GW3016A), gravitational filter samplers (37-mm diameter filter-Type AE inside a filter cassette, SKC Inc., Eighty Four, PA 15330, USA) and a EPAM-5000

real-time sampler manufactured by Environmental Devices Corporation (4 Wilder Drive Bldg. 15, Plaistow, NH 03865-2856, USA). Real-time PM data from the EPAM-5000 sampler were adjusted (or scaled) on a linear basis to the results from the gravimetric sampler. Adjustments were necessary because the EPAM-5000 measurements were consistently lower than those obtained from the gravimetric sampler (EPA, 2004b). The hourly average real time data recorded by the device were compared with the hourly average data collected by the built-in gravimetric filter and other gravimetric filter in other samplers. Correction factor was established and entered to the device software. The gravimetric results from the filters were considered to be more representative of the actual particulate levels than those measured with light-scattering optical devices.

Real time measurements of the concentration of NH_3 , SO_2 , NO_2 and H_2S were performed with a multi-gas electrochemical gas sensor (TG-501 DirectSense TOX multi-gas monitor sensor, GRAYWOLF™ Sensing Solutions, 12 Cambridge Drive, Trumbull, CT. 06611 USA). Additional measurements were obtained with RAE Systems® Gas Detection Tubes (RAE Systems, 3775 North First Street, San Jose, CA 95134 USA), data collected by detector tubes were used as indicator for the accuracy of data collected by the multi-gas electrochemical gas sensor as a part of QA/QC concepts. A Testo 435-2 (Testo Inc. 40 White Lake Road Sparta, N.J. 07871 - USA) multi-function instrument for indoor air quality measurements was used to measure the temperature, relative humidity, CO_2 concentration and absolute pressure. The following procedures were employed:

- Real time measuring of the total mass concentration of particulate matter and toxic gases was conducted at a sampling rate of 1 min.
- Measurements from the gravimetric filters and gas detection tubes were obtained in triplicate.
- The measurement methodology and protocol were developed in the lab and applied in the field, according to the procedure of Almuhanha (2007) and Almuhanha *et al.* (2008).

Statistical analysis: The data from this study were subjected to a two-way analysis of variance for the effect of house and week of age as the main effects and their interaction. Means were separated by use of Duncan's multiple range tests. Data were analyzed using the general linear model procedure of SAS software (SAS, 2000). Statistical significance was considered as $p \leq 0.05$ throughout the paper.

RESULTS AND DISCUSSION

Microclimatic conditions of the two broiler housing: The microclimatic conditions inside both broiler houses

Table 1: Mean, standard deviation and range of values (mg/m³) for TSP, PM₁₀ and PM_{2.5} during the experimental period

House	TSP			PM ₁₀			PM _{2.5}		
	Mean*	SD	Max**	Mean*	SD	Max**	Mean*	SD	Max**
H14	4.35a	2.17	7.83	2.26a	1.35	4.56	0.08a	0.05	0.17
H15	3.64a	2.07	6.83	1.79a	1.02	3.21	0.07a	0.04	0.14

*Column means followed by the same letter are not significantly different at 95% level of confidence.

**At M.V. house maximum values were observed in week 5 of the flock age

were compared with the outside climatic conditions to measure the effectiveness of the environmental control system. Fluctuations in the air temperature surrounding the birds play an important role in their growth rate, development and productivity. Fluctuations in air temperature caused by the ventilation control board were observed inside the broiler houses. The measured inside air temperatures ranged from 26.5-34.9°C with a mean of 30.75°C (SD = 3.18°C) for H14 and ranged from 23.8-34.41°C with a mean of 30.01°C (SD = 4.14°C) for H15. The inside relative humidity ranged from 22.19-41.03% with a mean of 31.6% (SD = 9.92%) for H14 and ranged from 22.19-41.04% with a mean of 32.86% (SD = 7.82 %) for H15. The outside air temperatures at the sampling time ranged from 15.17-29.92°C with a mean of 22.48°C (SD = 7.49°C) and the outside RH ranged from 20.73-49.4% with a mean of 33.1% (SD = 12%). This change in the inside environmental parameters are due to the management program to satisfy the birds growing needs.

The variation in the relative inside houses during the experimental period as a function of the growth cycle (in week) is shown in Fig. 3. Variations in the relative humidity occurred at the peak of the heating cycle, particularly in the first three weeks of the growth cycle. During the last two weeks of the growth cycle, the relative humidity increased because the air temperature was reduced according to the required air temperature and the age of the birds.

Particle mass concentration: The weekly average concentration of TSP (inhalable dust) inside both poultry houses is summarized in Table 1. The weekly average TSP inside the N.V. poultry house had significantly ($p < 0.05$) greater mean value (12.47 mg/m³) than M.V. poultry house (4.61 mg/m³) during the experimental period. The averages of (TSP) inside the two houses during the experimental period was 4.25 mg/m³ for H14 to 3.64 mg/m³ for H15. The average concentration of TSP in both houses was greater than or close to the acceptable range of the threshold for indoor air contaminants in livestock houses (3.4-3.7 mg/m³) proposed by Wathes (1994) and Donham and Cumro (1999a).

PM₁₀, PM_{2.5} concentration samples were taken every week. Houses were only in tunnel ventilation mode during this period. When the temperature decreases, the environmental controller reduces the number of tunnel

Table 2: Weekly average dust concentration (mg/m³) inside the broiler houses during the growth cycle

Week	TSP		PM ₁₀		PM _{2.5}	
	H14	H15	H14	H15	H14	H15
1	4.01	2.69	1.78	1.24	0.05	0.04
2	2.59	2.68	1.20	1.28	0.06	0.08
3	2.47	1.54	1.46	0.75	0.04	0.03
4	4.36	4.46	2.28	2.48	0.09	0.11
5	7.83	6.83	4.56	3.21	0.17	0.14

fans in operation, this action cause to increase in concentration of airborne particles with all sizes. At the commercial broiler barn, airborne dust concentration was observed to be highly affected by the barn ventilation rate. The PM concentration was changing depending on the operation of ventilation mood.

The weekly averages of PM₁₀ concentrations (thoracic dust) inside the two houses during the experimental period was 2.26 mg/m³ and 1.79 mg/m³ for H14 and H15 respectively and ranged between 0.75-4.56 mg/m³ and the weekly averages PM_{2.5} concentrations inside the two houses during the experimental period were 0.08 mg/m³ and 0.07 mg/m³ for H14 and H15 respectively and ranged between 0.03-0.17 mg/m³. In general, H15 was having lower concentration of airborne dust comparing with H14.

The weekly average PM₁₀ concentration (thoracic dust) inside the N.V. poultry house had significantly ($p < 0.05$) greater mean value (4.81 mg/m³) than M.V. poultry house (2.26 mg/m³) during the experimental period and the weekly average PM_{2.5} concentration inside the N.V. poultry house had significantly ($p < 0.05$) greater mean value (0.18 mg/m³) than M.V. poultry house (0.09 mg/m³) during the experimental period. In previous studies, dust concentrations in poultry houses varied from 0.02-81.33 mg/m³ for TSP (inhalable dust) and 0.01-6.5 mg/m³ for PM_{2.5} (respirable dust) (Ellen *et al.*, 2000).

The TSP, PM₁₀ and PM_{2.5} concentration was determined every week during the experimental period and the results are provided in Table 2. The dust concentration varied from week to week according to the amount of dust emissions, which was associated with the age of the birds.

Figure 4 shows the change in the airborne dust concentration during the air exchange process over 60 successive minutes. Fluctuations in the TSP concentration (inhalable dust) caused by the ventilation control board were observed. The TSP concentration

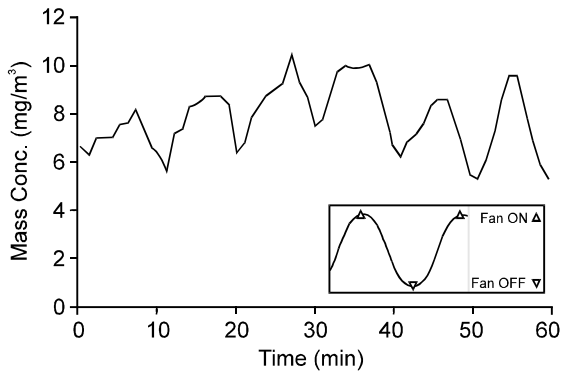


Fig. 4: Cyclic changes in airborne dust concentration inside the broiler house

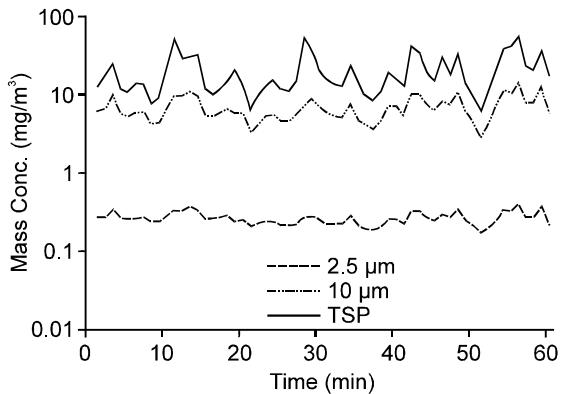


Fig. 5: Effect of air exchange on particles with different sizes inside the broiler house

varied over time during each ventilation cycle and the highest concentration of TSP was observed before the ventilation system was turned on. Alternatively, the lowest TSP concentration inside the broiler house was observed before the ventilation system was switched off. The effect of the air exchange rate on different sizes of airborne particles was examined and the results are shown in Fig. 5. The smallest airborne particles (TSP, PM₁₀ and PM_{2.5}) were slightly affected by the air exchange rate during the experimental period.

Gaseous contamination: During this study, ammonia (NH₃) and other toxic gases (SO₂, NO₂ and H₂S) concentrations were collected. Figure 6 shows the measured concentration of toxic gases (NH₃, SO₂, NO₂ and H₂S); these measurements suggested that ammonia is the most dominant toxic gas available in these poultry houses. At the commercial broiler barn, a total of toxic gases measurements were taken during the 35 day production cycle which indicated an overall increasing trend in ammonia concentration with bird age. It was also observed that the concentration did not show a considerable values until approximately halfway through the production cycle.

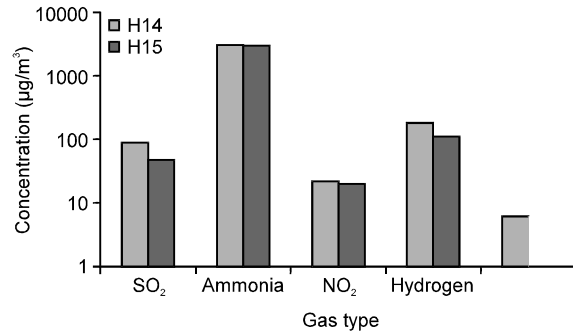


Fig. 6: Measured concentration of toxic gases (NH₃, SO₂, NO₂, H₂S)

The ammonia concentration did reach 1.33 and 5.2 mg/m³ for H14, H15 respectively until after day 28 of the cycle and then it increased by approximately 6.5 and 4.2 mg/m³ for H14, H15 respectively during the remaining 7 days of production. In addition, H15 shows a higher ammonia concentration with a percentage of 55% higher than H14 especially at week 4-5, this increase may due to differences in ventilation system efficiency.

The concentration of ammonia (NH₃) and other gases (CO₂, SO₂, NO₂ and H₂S) was measured during the growth cycle and the experimental data are shown in Table 3. Among other gases available in the poultry houses, ammonia was the most abundant toxic gas. Toxic gas measurements inside both houses were performed during the first 35 days of the growth cycle and an overall increase in the ammonia concentration was observed over time. The average concentration of ammonia gas (NH₃) inside the M.V. poultry house had significantly ($p < 0.05$) greater mean value (3.52 ppm) than N.V. poultry house (0.74 ppm).

The average concentration of ammonia gas (NH₃) inside H14, H15 was 1839.6 µg/m³ (2.63 ppm) and 3087.1 µg/m³ (4.41 ppm), respectively, as shown in Table 3. The average concentration in both houses was lower than the thresholds for indoor air contaminants in human and livestock housing (7 ppm for human and 11 ppm for animals) proposed by Donham and Cumro (1999b; 2002) and (Donham *et al.*, 2000). However, the concentration of ammonia inside the both houses exceeded this limit and reached 12498.8 and 17661 µg/m³ (17.86 and 25.2 ppm) at week 5 of the growth cycle.

The average concentration of hydrogen sulfide (H₂S) inside H14, H15 broiler house was 6.05 µg/m³ (0.01 ppm) and 8.6 µg/m³ (0.01 ppm), respectively, as shown in Table 3. The average concentration in both houses was lower than the threshold for indoor air contaminants in livestock housing units (5 ppm) proposed by Donham (1993; 1995), Donham and Cumro (1999b) and (Donham *et al.*, 2000).

Table 3: The concentration of NH₃, H₂S, CO₂, SO₂ and NO₂ inside the (H14, H15) poultry houses during the experimental period

	NH ₃ , µg/m ³		H ₂ S, µg/m ³		CO ₂ , ppm		SO ₂ , µg/m ³		NO ₂ , µg/m ³	
	H14	H15	H14	H15	H14	H15	H14	H15	H14	H15
Mean*	1839.6a	3087.1b	6.05a	8.58a	768.10a	804.60a	54.99a	132.20b	20.19a	43.30b
SD	3335.5	4184.7	4.71	7.26	406.77	320.72	59.34	124.39	11.27	31.58
Max	12498.8	17661.0	162.80	37.50	1312.50	1405.40	645.80	361.20	70.40	115.60

*Means followed by the same letter are not significantly different at 95% level of confidence

Table 4: Weekly average ammonia concentration (mg/m³) at H14, H15 during the growth cycle (5 weeks)

	H14			H15		
Week	Mean	SD	Max	Mean	SD	Max
1	0.06	0.02	0.12	0.05	0.01	0.06
2	0.16	0.04	0.20	0.46	0.05	0.50
3	0.13	0.04	0.27	0.19	0.19	0.63
4	1.18	0.73	5.53	5.20	1.99	16.34
5	7.75	2.05	12.50	9.40	1.89	17.66

The average concentration of carbon dioxide gas (CO₂) inside the H14, H15 broiler house was 768.1 ppm and 804.6 ppm, respectively, as shown in Table 3. The average concentration in both houses was equal to the threshold for indoor air contaminants in livestock housing units (1540 ppm) proposed by Donham (1993; 1995), Donham and Cumro (1999b) and (Donham *et al.*, 2000).

As shown in Table 3, the average concentration of sulfur dioxide (SO₂) inside the M.V. poultry house had significantly ($p < 0.05$) greater mean value (0.08 ppm) than N.V. poultry house (0.04 ppm), however, the average concentration of nitrogen dioxide (NO₂) inside the M.V. broiler house (0.02 ppm) did not significantly differ ($p > 0.05$) from N.V. poultry house (0.02 ppm).

As shown in Table 3, the average concentration of sulfur dioxide (SO₂) inside the H14, H15 broiler houses was 54.98 µg/m³ and 132.23 µg/m³ and the average concentration of nitrogen dioxide (NO₂) was 20.19 µg/m³ and 43.3 µg/m³, respectively.

For both houses, the weekly average ammonia concentration during the growth cycle (5 weeks) in both houses (Table 4), the ammonia concentration gradually increased from week 1 until the end of week 2. Next, the concentration of ammonia decreased at the end of week 3. At the beginning of week 4, the ammonia concentration increased to a maximum mean value at the end of growth cycle. The maximum concentration of ammonia was 12.50, 17.66 mg/m³ (17.9, 25.2 ppm) and was observed during the last 5 days of the growth cycle. The ammonia concentration in the H14 and H15 broiler houses was monitored continuously for a 24-hr period and the results are plotted in Fig. 7 suggested that the ventilation system in H14 was more efficient in reducing ammonia concentration at the day time which was expected because of the longer time of operation of exhaust fans for heat removal at day time comparing with night time. It is possible that H15 was having some

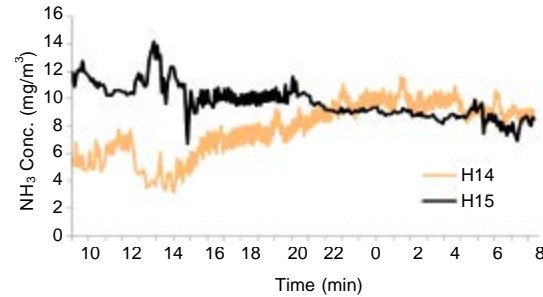


Fig. 7: Continuous measurement of ammonia concentration during a 24-hr period

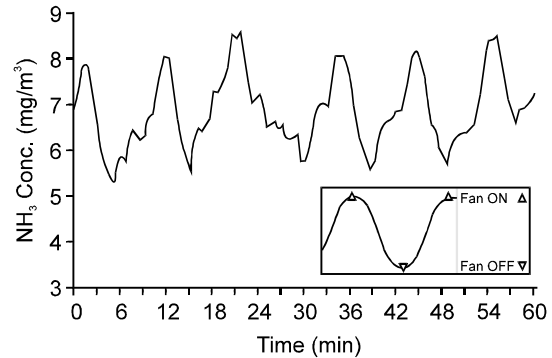


Fig. 8: Cyclic changes in the ammonia concentration due to ventilation cycles

technical problems in exhaust fans operation sequence. The ammonia concentration was strongly affected by the air exchange rate.

Cyclic changes in the ammonia concentration were attributed to the use of the ventilation system, as shown in Fig. 8.

During study period it was observed that the floor cover (sand) for H15 was having higher moisture than H14, there are many possibilities causing that, however this may explain the fact of that the H15 was having higher concentration of ammonia and lower concentration of airborne dust comparing with H14. There were significant differences among birds under the two houses in average immune response against Newcastle Disease (ND) (Table 5).

In addition the superiority of house 14 Birds recorded the highest values for shank length, body weight, weight gain and feed conversion too. Current results are in

Table 5: The production and immunological parameters inside the (H14, H15) poultry houses during the experimental period

	Shank length cm	ND titer	Average BW	Average weekly gain	Average weekly feed consumption	Average weekly feed conversion
H14	3.71a	8.40a	845.53a	335.13a	592.6b	1.62b
H15	3.41b	7.27b	787.73b	291.0b	626.3a	1.97a

Column means followed by the same letter are not significantly different at 95% level of confidence

agreement with the previous research work of Charles and Payne (1966); Quarles and Kling (1974); Reece and Lott (1980) which indicated that chickens exposed to ammonia showed reductions in feed consumption feed efficiency, live weight gain and carcass condemnation.

In addition the ammonia effect on performance have been indicated previously in agreement with the current research results, where Miles *et al.* (2004); Beker *et al.* (2004) reported that ammonia can reduce bird growth performance and increase susceptibility to diseases and increase subsequent mortality (Kristensen and Wathes, 2000).

The current results suggested that the increase of air contaminants and gases negatively affect the general productive performance and immune response under commercial conditions.

Conclusion: From the results of the present study, the following conclusions could be drawn:

- The weekly average concentration of TSP in the H14 and H15 broiler houses, which is equivalent to the inhalable dust content, was 4.25 and 3.64 mg/m³, respectively. Both values were greater than the suggested threshold for indoor air contaminants in livestock housing units of 3.4-3.7 mg/m³ proposed by Wathes (1994) and Donham and Cumro (1999a,b).
- The weekly average PM₁₀ concentration in the H14 and H15 broiler houses, which is equivalent to the thoracic dust concentration, was 2.26 and 1.79 mg/m³, respectively. The weekly average PM_{2.5} concentration in the H14 and H15 broiler house was 0.08 and 0.07 mg/m³ respectively.
- The concentration of airborne dust and toxic gases in both boiler houses was strongly affected by the air exchange rate.
- Ammonia was the most common toxic gas in both broiler houses; however, high concentrations of ammonia were not observed until the second half of the growth cycle. The ammonia concentration increased by approximately 9000 µg/m³ during the remaining 2 weeks of production.
- H15 shows lower concentration of airborne dust comparing with H14, however it shows a higher ammonia concentration with a percentage of 55% higher than H14 especially at week 4-5.
- The concentration of toxic gases was measured (NH₃, CO₂, SO₂, NO₂ and H₂S) and the results revealed that ammonia was the most abundant

toxic gas in both houses. The majority of toxic gases did not exceed the suggested thresholds.

- The current results suggested that the increase of air contaminants and gases negatively affect the general productive performance and immune response under commercial conditions.

ACKNOWLEDGMENTS

The author is grateful acknowledge deanship of scientific research at King Faisal University (KFU) for financial support of the current research work. Thank also extended to the commercial poultry company at Al-Ahsaa for facilitate this research work.

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