Ammonia and Carbon Dioxide Concentrations in a Sheep Barn

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ABSTRACT : Indoor air quality in animal barns directly affect to animal productivity. Measuring the pollutants in animal barns proves the negative effects of gases on health of animals and workers. Most studies in this context focused on some pollutant gases such as ammonia, carbon dioxide, methane and hydrogen sulfide in dairy barn and poultry houses. Less attention in studies in scientific literature was paid to sheep barns which may have more important portion than other animals for the animal production sector of some countries. This paper revealed the concentrations of ammonia (NH_3) and carbon dioxide (CO_2) in naturally ventilated sheep barn in Bursa region, western Turkey. Also indoor environmental conditions such as temperature and relative humidity were measured simultaneously with pollutant gas concentrations. Regression and variance analyzes were applied to assess data collected in sheep barn whole over the study period. The average NH_3 concentration during the study was 15 ppm for exhaust and 0.77 ppm for ambient, CO_2 concentration was 1022 ppm for exhaust and 457 ppm for ambient. There was significant difference among measurement days for exhaust NH_3 and CO_2 concentrations ($P< 0.001$). The lowest NH_3 concentration was 8 ppm while lowest CO_2 concentration was 277 ppm, and the highest concentrations were 38 ppm for NH_3 and 1700 ppm for CO_2. Also minimum, maximum, average values for indoor temperature were 16.06°C, 26.53°C, 20.69°C, respectively, while minimum 43.42%, maximum 89.6%, average 71.23% values for relative humidity were obtained. According to regression analyze results, the exhaust NH_3 concentration related statistically significant with air velocity. The standardized coefficients suggest that indoor temperature and relative humidity sustained the greater effects on CO_2 concentrations ($P< 0.001$).
Keywords: Sheep Barns, Indoor Temperature, Pollutant gas concentration, Ammonia, Carbon Dioxide,

Bir Koyun Ağılında Amonyak ve Karbondioksit Konsantrasyonları

ÖZET : Hayvan barınaklarında iç ortam hava kalitesi hayvanların verimliliğini doğrudan etkiler. Hayvan barınaklarında kirleticilerin ölçümleri hayvan ve çalışan sağlığı üzerine olan olumsuz etkileri ortaya koymuştur. Bu amaçla yapılan birçok çalışmada, süt sığırı ahırları ile kanatlı kümeslerindeki amonyak, karbondioksit, metan ve hidrojen sülfit gibi kirleticiler üzerine yoğunlaşmıştır. Bilimsel literatürde, bazı ülkelerin en önemli hayvancılık sektörlerden birisi olan koyunculuk işletmelerine daha az yer verilmiştir. Bu çalışma, Bursa bölgesinde faaliyet gösteren doğal havalandırmalı koyun ağılında amonyak ve karbondioksit konsantrasyonlarına ilişkin ölçüm sonuçlarını göstermektedir. Ayrıca, sıcaklık ve bağıl nem gibi iç ortam çevre koşulları da kirletici gaz konsantrasyonları ile birlikte eş zamanlı olarak ölçülmüştür. Çalışma periyodu süresince koyun ağılında elde edilen verilerin değerlendirilmesi için varyans ve regresyon analizleri uygulanmıştır. Çalışma sonunda ortalama NH_3 konsantrasyonu çıkış açıklığında 15 ppm ve giriş açıklığında 0.77 ppm ölçülürken, CO_2 konsantrasyonu çıkış açıklığında 1022 ppm ve giriş açıklığında 457 ppm olarak ölçülmüştür. Yapılan istatistiksel analiz sonucunda çıkış açıklığında ölçülen NH_3 ve CO_2 konsantrasyonları ölçüm günleri arasında önemli derecede farklıdır ($P< 0.001$). En düşük CO_2 konsantrasyonu 277 ppm iken en düşük NH_3 konsantrasyonu 8 ppm olarak gerçekleşmiştir. En yüksek konsantrasyon değerleri NH_3 için 38 ppm ve CO_2 için 1700 ppm olarak ölçülmüştür. Ayrıca minimum, maksimum ve ortalama bağıl nem değerleri sırasıyla %43.42, %89.6 ve %71.23 iken iç ortam sıcaklığı sırasıyla 16.06°C, 26.53°C ve 20.69°C olarak ölçülmüştür. Regresyon analizi sonuçlarına göre, çıkış açıklığı NH_3 konsantrasyonu, hava hızı ile istatistiksel olarak önemli ilişki içerisindedir. Standardize edilmiş regresyon katsayısı iç ortam sıcaklığı ve bağıl neminin CO_2 konsantrasyonları üzerinde önemli bir etkisinin olduğunu göstermiştir.
Anahtar Kelimeler: Koyun Barınakları, İç Ortam Sıcaklığı, Kirletici Gaz Konsantrasyonları, Amonyak, Karbondioksit

INTRODUCTION

Sheep production is one of the most dynamic sectors of the rural economy in Turkey. According to FAO'sdatabase in 2013, there are about 30 million sheep (18 million for meat and 12 million for milk) in Turkey and 295000 tones sheep meat were produced in 2013 which means 16 kg per sheep. Sheep production in 2014 consisted of 56% of total animal existence in Turkey, 11% of meat production and 6% of milk production (FAO, 2014). These numbers exhibit significance of sheep production for Turkish families in rural areas.

Animal agriculture is one of the major sources of gases pollutants in atmosphere. Animal barns emitted significant concentrations of ammonia (NH_3), methane (CH_4), hydrogen sulfide (H_2S), carbon dioxide (CO_2) released from farming activities, manure and feed composition. The most of these pollutant gases are the greenhouse gases which cause some environmental problems such as global warming. Also they have some health effects on animal, farmers and worker and their welfare. Pollutant gases in animal barns are emitted to atmosphere surrounding barn via ventilation system. Therefore their health effects may affect people living near animal production facilities. The current expectation of society from animal producer is not only to provide quality products but also to respect the animal welfare and environment (Dockes et al., 2006). Increasing the number of modern livestock enterprises to answer present anticipation is causing to rise the concentration of greenhouse gases. Increase in these gases concentrations are becoming even greater concern of their negative effect on atmosphere and earth climate balance (Borhan et al., 2012).

There is a limited number of studies on measuring pollutant gas concentrations in sheep barns in the literature. On the contrary, many of studies were conducted to quantify pollutant gas concentrations in dairy cattle barns (Zhang et al., 2005; Bjorneberg et al., 2009) and poultry houses (Hörnig et al., 2004; Guiziou and Beline, 2005; Burns et al., 2008) in Europe and the USA. Also, there are few studies to determine some pollutant gas concentrations in animal barns in Turkey. In these studies, NH_3 concentration was in broiler houses (Atilgan et al., 2010; Simsek et al., 2013), dairy barns (Simsek et al., 2012) and laying hen houses (Kocaman et al., 2006). Many studies underlined that the pollutant gas concentration in animal barns should be examined to quantify pollutant gas emissions from animal barns and to assess their effect on air quality in atmosphere surrounding these barns. Also, pollutant gas concentrations should be investigated in these barns to have the knowlwdge if criticle levels for the workers and sheep health were reached.

The aim of this study was to determine the concentration of pollutant gases including NH_3 and CO_2 in naturally ventilated sheep barn in Bursa. Barn temperature (T), relative humidity (RH) and ventilation rate (VR) were also determined on a continuous basis to examine environmental conditions in sheep barn. This study provides some beneficial results to help farmers, animal scientist and veterinary in the sheep production facilities.

MATERIAL and METHODS

Characteristics

A closed sheep barn contains sheep barns characteristics with natural ventilation selected at a sheep production facility located in Bursa, western Turkey. The monitored barn consisted of a dimension of 43 × 19.8 m (L × W) with a West-East orientation. The barn was divided to different rooms for different age level of sheep like new born or ram. The totally 656 sheep were housed in this barn. There was no fan in the barn for ventilation, fresh air was taken through sidewall openings and released by the chimney openings. House ventilation rate was controlled by eight windows on sidewall and eight chimneys on the top of roof. Dimensions of each windows and chimneys were 70 × 100 cm and 50 × 50 cm, respectively. Sheeps were free for feeding and drinking accross to the barn. Sheep feed consisted of silage (corn, wheat and alfalfa), compound premix. Manure was released directly on the litter. Water and feed consumption weren't automatically recorded. Manure was cleaned out annually and transported to another farm as fertilizer use. Manure was cleaned twice a year and stalk and straw were used as annimal bedding materials by adding twice a month on the dirty layer based on the producer observation. Bedding material was used for four weeks over the syudy period. A worker was in charge of taking care of feeding of animals and other management process in sheep barn.

Gas concentration and environmental conditions measurement

For this study, NH_3 and CO_2 concentrations and indoor conditions including temperature and relative humidity were determined in May of 2014. Because, this study includes preliminary experiment results for indoor air quality in sheep barns project of two years. A multi-gas analyzer (MultiRAE IR Lite RAE systems, San Jose, CA, USA) with electrochemical and NDIR sensors (NH_3: accuracy <±1% , precision 1ppm, CO_2: accuracy <±5% , precision 10 ppm) was used to detect pollutant concentrations. Multi-gas analyzers used in the study were calibrated once a three months. Two multi-gas analyzers were placed inlet and exhaust openings on sidewall of barn (Figure 1). Pollutant gas concentrations were measured continuously over 24 h for four days. Indoor air temperature, relative humidity (RH) and air velocity in barn were monitored at 5 min intervals throughout the experiment by using portable temperature/RH/air velocity meter with hot-wire probe (Model 435, Testo).

Airflow rates calculation

For natural ventilated animal barns, there are some indirect methods to calculate airflow rate. In this study, the barn ventilation rate was calculated using a CO_2 balance method based on CO_2 production of sheep (Albright, 2000).

$$Q = \frac{V_{CO_2} \times 10^6}{C_{e,CO_2} - C_{i,CO_2}} \times P_{CO_2} \qquad (1)$$

Where; V_{CO_2} is CO_2 generation rate of the sheep barn ($m^3 \cdot h^{-1} \cdot barn^{-1}$), Ce, CO_2 and Ci, CO_2 are exhaust and inlet CO_2 concentrations of the sheep barn at 20°C ($mg \cdot m^{-3}$), and P_{CO_2} is CO_2 density (1.977 $kg \cdot m^{-3}$ at 20°C).

Data analysis

JMP 7 was used for data processing and descriptive statistics such as maximums, minimums, standard deviations and means. Two different statistical analyzes were applied to analyze the data collected. The analysis of variance with general linear model was applied to determine differences among pollutant gas concentrations according to diurnal variation or daily variation. Also, regression analyze was done to reveal relationship between environmental climatic conditions and pollutant gas concentrations.

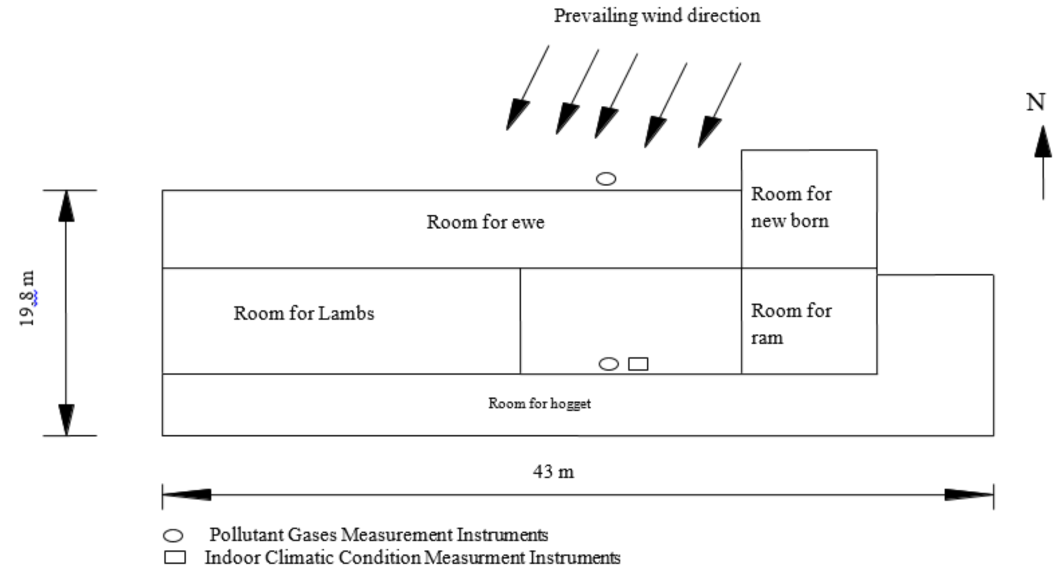

Figure 1. Data collecting locations in the barn.
Şekil 1. Çalışmanın yürütüldüğü koyun ağılında ölçüm yapılan noktalar

RESULTS and DISCUSSION

Outdoor and Indoor environmental conditions

Table 1 shows daily average outdoor temperature, relative humidity and air velocity. The descriptive statistics of indoor temperature (T), relative humidity (RH), air velocity (AV) and ventilation rate (V) were given in Table 2. The indoor temperature varied from 16.06°C to 26.53°C while relative humidity ranged between 43.42% and 89.6%. Despite a large variation in relative humidity, the indoor temperature remained narrow interval. These stable indoor temperatures were derived by appropriate ventilation rates. The ventilation rates varied from 2.29 to 5.40 $m^3.s^{-1}\cdot barn^{-1}$. The differences for T, RH and AV between measurement days were significantly different in the study ($P<0.01$ for T and RH and $P<0.05$ for AV).

Table 1. The daily average outdoor environmental conditions
Çizelge 1. Günlük ortalama dış ortam çevre koşulları

Measurement Day	Air Velocity ($m.s^{-1}$)	Temperature (°C)	Relative Humidity (%)
16.05.2014	3,2	18,7	65,16
17.05.2014	2,5	17,7	66,70
18.05.2014	1,9	16,6	65,36
19.05.2014	2,1	18,2	60,58

The diurnal variation was observed in indoor environmental conditions during the study (Figure2). The average day and night time indoor air temperatures (T), relative humidity (RH) and velocity (V) were 23.5°C and 19.2°C, 67% and 80%, 0.10 $m\cdot s^{-1}$ and 0.08 $m\cdot s^{-1}$, respectively. Also, the differences between day and nighttime variables were statistically significant for T and RH ($p<0.01$) and V ($p<0.05$).

Ammonia and carbon dioxide concentrations

Table 3 summarizes descriptive statistics of measured gas concentrations the barn atmosphere. The average exhaust and ambient NH_3 and CO_2 concentrations were defined as the average of the hourly mean concentrations measured at ambient and exhaust openings. As shown in Table 2, the minimum, maximum and standard deviation values of exhaust concentrations were measured as 8.00, 38.00, and 5.39 ppm for NH_3, 277, 1700, and 293.45 ppm for CO_2 throughout study, respectively. Overall mean values of exhaust NH_3 and CO_2 concentrations were averaged 16 ppm and 1032 ppm, respectively. As ANOVA results show, both of ambient and exhaust concentrations of NH_3 and CO_2 were differed significantly among four measurement days ($P< 0.0001$).

Given in Table 2. The descriptive statistics of indoor environmental conditions

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Çizelge 2. İç ortam çevre koşullarının tanımlayıcı istatistikleri

Measurement Day	Parameter	Air Velocity ($m.s^{-1}$)	Temperature (°C)	Relative Humidity (%)	Ventilation Rate ($m^3.s^{-1}.barn^{-1}$)
16.05.2014	avg	0.124^a	23.02^a	74.18^a	3.62
	min	0.0	20.47	12.47	2.47
	max	0.23	26.53	78.01	5.31
	sd	0.04	2.01	11.83	1.09
17.05.2014	avg	0.08^b	23.02^a	73.66^a	3.49
	min	0.03	16.16	44.83	2.31
	max	0.4	25.91	83.41	4.89
	sd	0.06	2.64	9.85	0.87
18.05.2014	avg	0.08^b	$20.42b^c$	70.13^b	3.41
	min	0.03	16.73	54.33	2.29
	max	0.4	24.4	89.6	5.15
	sd	0.06	24.54	9.85	0.92
19.05.2014	avg	0.06^c	19.96^c	62.42^c	3.68
	min	0.08	16.06	55.84	2.33
	max	0.38	25.76	83.16	5.40
	sd	0.05	3.18	7.75	1.05

Min, minimum; Avg, average; Max, maximum; SD, standard deviation.
$^{a-c}$Means in a column with different superscripts significantly differ ($p<0.01$ for T, RH, $p<0.05$ for AV).

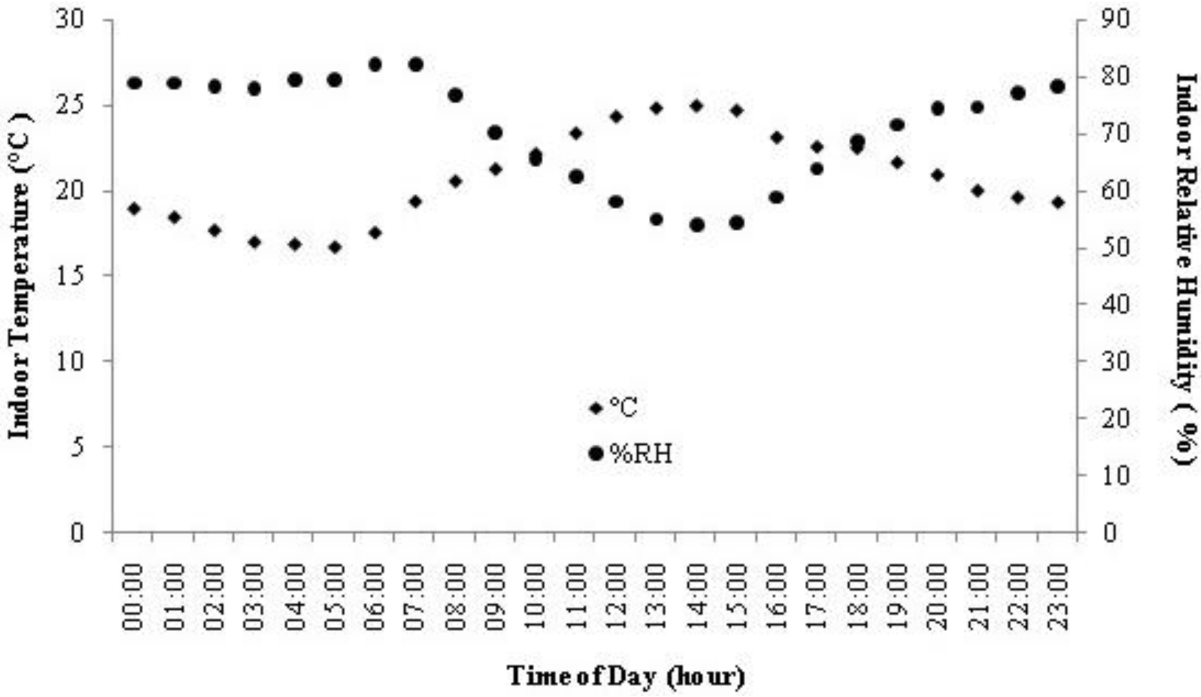


Figure 2. Diurnal variation in indoor environmental conditions during study period.
Şekil 2. Çalışma periyodu süresince iç ortam çevre koşullarındaki saatlik değişim

Table 3.The descriptive statistics of NH_3 and CO_2 concentrations
Çizelge 3. NH_3 ve CO_2 konsantasyonlarının tanımlayıcı istatistikleri

Day	Type	NH_3 concentration (ppm)				CO_2 concentration (ppm)			
		Min	Avg	Max	Sd	Min	Avg	Max	Sd
Day 1	Ambient	12	22.78^a	35	3.98	250	455.48^a	1500	277.84
	Exhaust	14	24.56^a	38	4.74	272	1055.55^a	1600	310.81
Day 2	Ambient	8	13.84^b	27	4.06	254	454.59^{ab}	1600	255.04
	Exhaust	10	17.20^b	29	4.66	283	1037.43^a	1600	274.10
Day 3	Ambient	7	9.14^c	13	1.12	251	497.84^b	1700	261.49
	Exhaust	8	11.71^c	18	2.01	297	1032.72a^b	1700	295.97
Day 4	Ambient	6	8.23^d	13	1.08	257	420.52^b	1500	280.33
	Exhaust	8	10.29^d	16	1.22	300	1001.72^b	1600	305.54

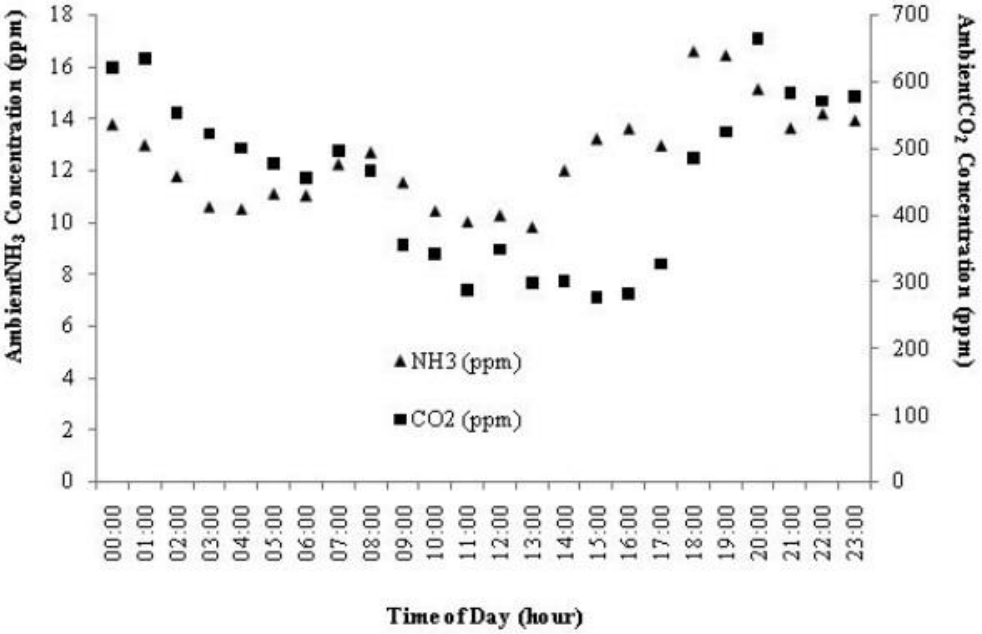
Min, minimum; Avg, average; Max, maximum; SD, standard deviation.
$^{a-d}$Means in a column with different superscripts significantly differ (p<0.0001).

Figure 3 show the hourly averaged diurnal profile for ambient and exhaust NH_3 and CO_2 concentration. While exhaust concentrations for NH_3 and CO_2 showed a clear diurnal pattern depending on sheep activity, ambient temperature and barn airflow rate, ambient concentrations for NH_3 and CO_2 illustrated no clear diurnal variations according to hourly pollutant gas concentrations. The exhaust CO_2 concentrations patterns generally decreased during the early to mid-morning hours and begin to increase in the late afternoon (Figure 3). The exhaust NH_3 concentrations illustrated a wavy diurnal pattern and decrease from early morning to noon. After noon hours, NH_3 concentrations increased until early evening hours. The average NH_3 and CO_2 exhaust concentrations in day time were 14.66 and 1035.79 ppm, respectively. The minimum and maximum NH_3 and CO_2 exhaust concentrations were obtained at noon and afternoon times. Since the exhaust NH_3 and CO_2 concentrations are substantially affected by house air flow rates, the airflow rate varied with ambient temperature, this interaction among environmental conditions created diurnal patterns of NH_3 and CO_2 concentrations.

Pollutant gas concentrations in sheep barns affect workers and animals health. Some limits obtained by countries to protect workers' health and it is based on time-weighted average (TWA) over 8 h and a short exposure threshold limits. The exposure limit of NH_3 was established as 20 ppm for short-term exposure and 50 ppm for TWA over 8 h for Turkish regulations (Kilic, 2013). Ammonia is an irritant gas with a sharp, pungent odor. It could irritate eyes and throat at low concentrations. Carbon dioxide is a asphyxiate gas no odor. Higher concentrations cause drowsiness, headaches and increasing breathing. It could be fatal at 300,000 ppm for 30 minutes (Anonymous, 2009).

Relationship of pollutant gases concentration and environmental conditions

In order to examine the impact of the indoor climate conditions on NH_3 and CO_2 concentrations, the concentrations of pollutant gases were correlated to air velocity, temperature and relative humidity values measured in monitoring sheep barn. Also regression analyzes were applied on NH_3 and CO_2 concentrations and indoor climatic conditions. Scatter plots of pollutant gases concentrations versus indoor climatic conditions are shown in Figures 4. Depend on low regression coefficient between variables, there was no significant relationship between temperature and ammonia concentration but there was a negative relationship between temperature and carbon dioxide. The ventilation rates increases linearly to meet sheep demand about indoor temperature. Therefore, the concentrations of pollutant gas decrease with increasing ventilation rates in barn. The results of regression analysis of the NH_3 and CO_2 concentrations in the barn are given in Table 4. Based on regression analyzes, the exhaust NH_3 concentration related statistically significant with air velocity. The standardized coefficients suggest that indoor temperature and relative humidity had the great effects on CO_2 concentrations ($P< 0.001$).



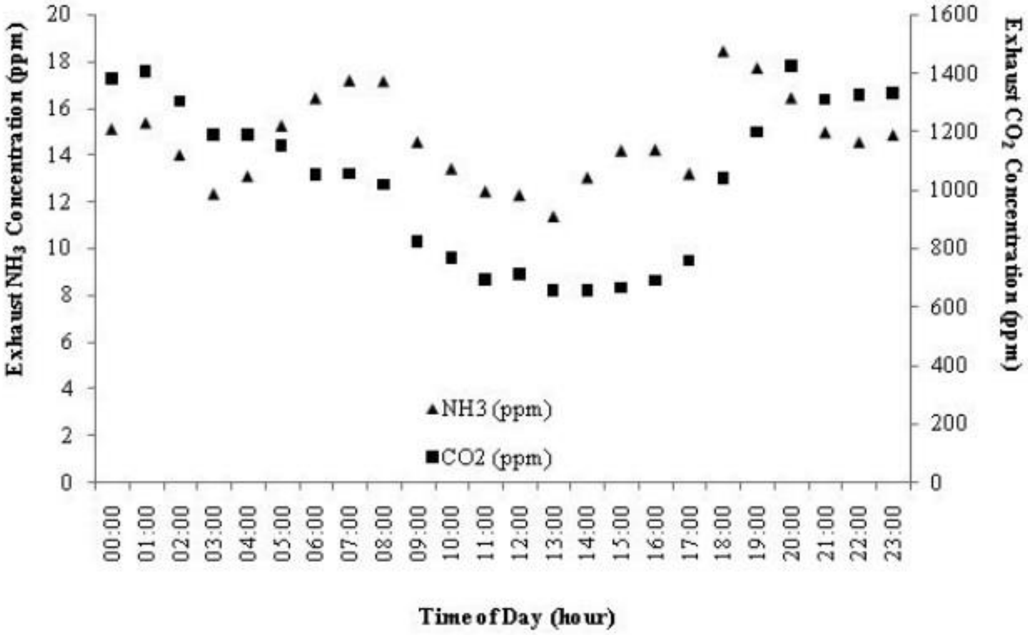


Figure 3. Diurnal variation in exhaust and ambient NH_3 and CO_2 concentrations during study period.
Şekil 3. Çalışma periyodu süresince iç ve dış ortam NH_3 and CO_2 konsantrasyonlarındaki saatlik değişim

Table 4. Statistics of relationship between gas concentrations with inlet and exhaust environmental conditions
Çizelge 4. Gaz konsantrasyonları ile i. dış ortam çevre koşulları arasındaki ilişkiye ait istatistikler

Term	Type	NH_3			CO_2		
		SD	t ratio	Prob>|t|	SD	t ratio	Prob>|t|
Air velocity	Ambient	2.999	-7.96	<.0001	104.619	-1.70	0.0894
	Exhaust	2.831	-7.55	<.0001	110.737	-2.33	0.0199
T	Ambient	0.137	0.21	0.8360	4.789	-4.39	<.0001
	Exhaust	0.129	-0.78	0.4352	5.069	-4.45	<.0001
RH	Ambient	0.035	-4.08	<.0001	1.243	9.58	<.0001
	Exhaust	0.033	-2.63	0.0087	1.315	10.67	<.0001

SD, standard deviation; T, temperature; RH, relative humidity.

The correlation coefficient between pollutant gas concentrations and climatic conditions were low in this study. According to correlation analysis there is a negative correlation between NH_3 and CO_2 concentrations and temperature and air velocity, but relative humidity has a positive effect on pollutant gas concentrations (Table 5). As a result of condition with minimum ventilation, pollutant gases were accumulated inside atmosphere in the animal barn. Although the correlation coefficient showed a negative relationship between temperature and exhaust NH_3 concentration (Figure 4), this relationship was quite weak (R2 = 0.07). Figure 4 also shows a weak negative relationship between air velocity and exhaust NH_3 concentrations. But this relationship is significant statistically (Table 4).

Table 5. Correlations coefficients for NH_3 and CO_2 concentrations and indoor climatic conditions
Çizelge 5. NH_3 ve CO_2 konsantrasyonları ve iç ortam iklim koşulları arasındaki ilişkiye ait korelasyon katsayıları

	NH_3 ambient	CO_2 ambient	NH_3 exhaust	CO_2 exhaust
Air velocity	-0.0875	-0.0012	-0.0151	-0.0125
Temperature	-0.1391	-0.0517	-0.1209	-0.0247
Relative humidity	0.2446	0.0145	0.1415	0.1839

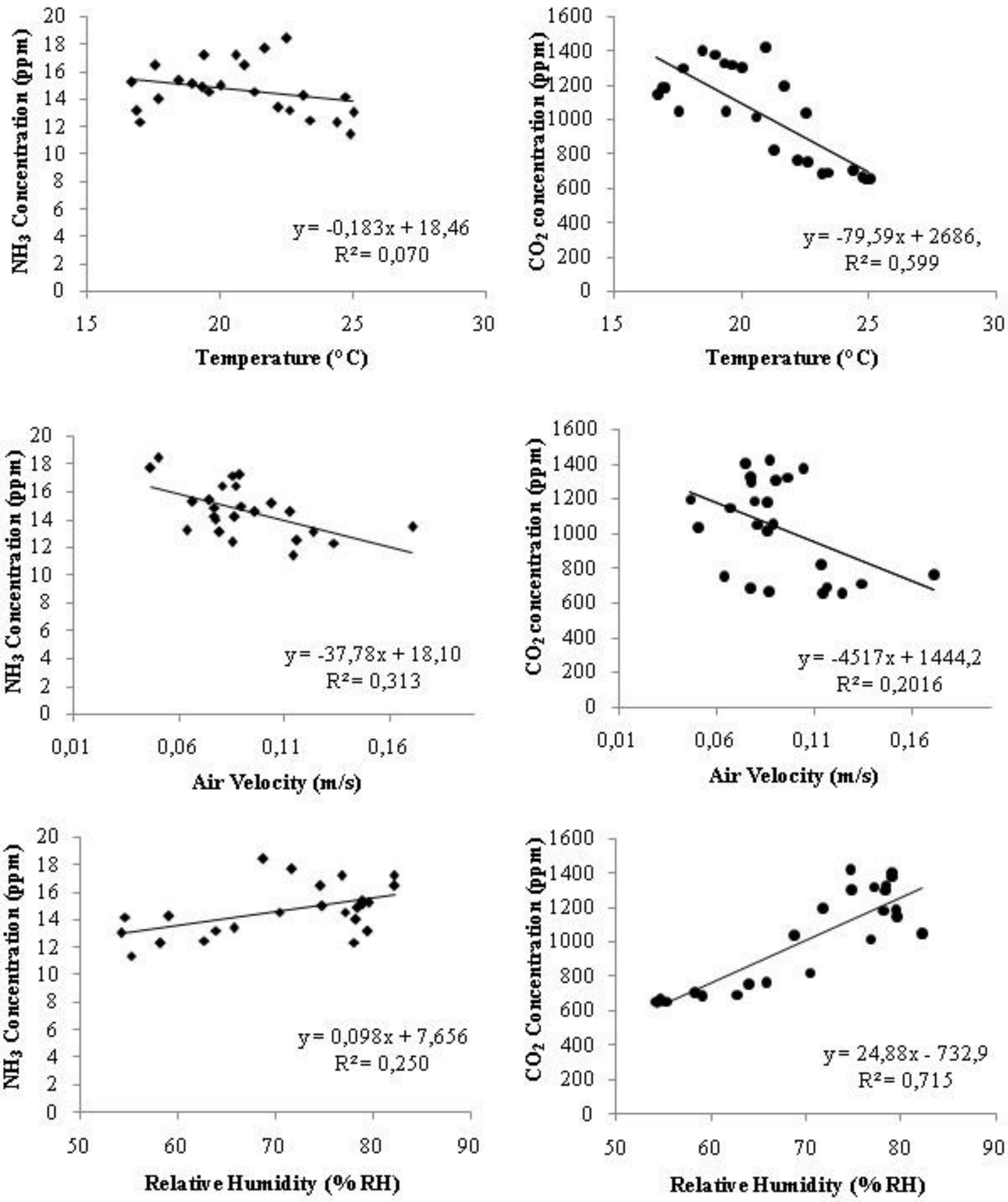


Figure 4. Relationship between pollutant gas concentrations and temperature, air velocity and relative humidity
Şekil 4. Kirletici gaz konsantrasyonları ve sıcaklık, hava hızı ve bağıl nem arasındaki ilişki

Since, there is a limited number of study on measurement of pollutant gas concentrations in sheep barns, our results compared with NH_3 and CO_2 concentrations in different animal barns. One of the studies on sheep barns, Papanastasiou et al., (2011) measured particulate matter concentration in a sheep barn in Greece. But their study didn't cover any pollutant gas in sheep barn atmosphere.

Several studies have previously been carried out to examine pollutant gases concentration and emissions in different animal barns in Turkey. NH_3 and CO_2 concentration was measured in broiler houses (Atilgan et al., 2010; Simsek et al., 2013), dairy barns (Simsek et al., 2012) and laying hen houses (Kilic and Yaslioglu, 2014; Kocaman et al., 2006). According to Simsek et al. (2013), average NH3 concentration in layer house was measured around 5 ppm in summer season. NH_3 concentrations in Turkish dairy barns varied 0.4 ppm to 9 ppm in a summer season (Simsek et al., 2012). Kilic and Yaslioglu (2014) reported lower values for NH_3 concentrations in a laying hen house compared with this study results. Summer NH_3 and CO_2 concentrations ranged 7-11 ppm and 533-904 ppm, respectively in their study.

The many of studies have been conducted to quantify pollutant gas concentrations in animal barns in Europe and in the US. Calvet et al. (2011) conducted a study to characterize gas emissions from a Mediterranean broiler farm. In their study, NH_3 concentration was ranged between 8 and 35 ppm for two rearing period and CO_2 concentration was ranged between 1000 ppm and 5000 ppm. Casey et al. (2010) found that average NH_3 concentration in an US broiler house was measured as 21 ppm by portable measurement unit and 17 ppm by FTIR for a spring month. Wang-Li et al. (2013) conducted an extensive study of NH_3 concentration in layer houses with a manure belt and high rise (HR) cage systems in North Carolina, USA. They measured 2-year mean NH_3 concentrations as 23 ppm at the exhaust fans in the HR houses. Fabbri et al. (2007) measured NH_3, CH_4, nitrous oxide (N_2O) and particulate matter (PM2.5 and PM10) emissions from two different houses for laying hens in Italy. They detected average NH_3 concentration with 3 ppm. The overall average CO_2 concentration as measured by Dobeic and Pintaric (2011) for monitored seven layer hen houses in Slovenia was reported 758 ppm in exhaust air.

Zhao et al. (2007) collected data on concentrations of pollutant gases, particulate matter and odor on two new large dairy facilities with naturally ventilated free stall barns and outside manure storage from March to August 2003 and 2004 in Ohio, USA. The NH_3 and CO_2 concentrations averaged 2.2 ppm and 476 ppm for farm 1 and 1.5 ppm and 365 ppm for farm 2 , respectively. Zhang et al. (2005) which is an USA study, indicated that NH_3 concentration in dairy cattle barns were changed from 2.1 ppm to 20 ppm. In some European Studies, average NH_3 concentrations were reported 5.3 ppm (Jungbluth et al., 2001) and 8.2 ppm (Snell et al., 2003).

According to results of studies in literature for different animal species, overall average NH_3 concentrations (16 ppm) obtained in this study was lower than those in dairy cattle barns, layer and broiler houses. When comparison with Turkish studies, NH_3 and CO_2 concentrations measured in this study were higher than concentrations values obtained in other animal barns. This situation in NH_3 and CO_2 concentrations may be caused by differences in characteristics of manure, feed composition, litter conditions and reactions and removing time of litter within the sheep barn during the monitoring period. NH_3 and CO_2 concentrations in monitored sheep barn are acceptable in comparison with OSHA and NIOSH indoor air quality standards which are 25 and 50 ppm for NH_3 and 5000 ppm for CO_2. But they are higher than the threshold values recommended by some Turkish regulations which was adapted to similar European Union regulations for worker's heath. They recommended threshold value for NH_3 as 14 ppm for long time exposure (Kilic, 2013). For sheep health and welfare in the barn, CIGR (1992) recommended 20 ppm for NH_3 and 3000 ppm for CO_2 as permissible maximum concentrations. The NH_3 concentrations measures in this study were higher than thresholds his report for some hours in early morning and late night. According to these results, it can say that sheep in monitored sheep barn may have welfare problem in terms of air quality within the barn.

CONCLUSION

The climatic conditions and air quality are one of the most important environmental conditions in animal barns. These conditions can affect animal performance and also animal's health. Moreover, some animal species such as sheep and chickens are known to be most sensitive against environmental conditions in animal barns. Therefore the sheep producers are instructed via studies conducted on air quality and climatic conditions in sheep barns. There is limited number of study about sheep barns in literature. The producers can be instruct and raised their awareness via increasing number of study on environmental conditions in sheep barns. This study includes some beneficial knowledge for sheep producers and animal scientist. Our results indicate that pollutant gases concentrations can arrive critical levels in some hours in sheep barn. The providing enough ventilation rates during these critical hours of day may obtain to reduce NH_3 and CO_2 concentrations. Therefore sheep welfare can sustain in even these critical hours. Using regression equation developed in this study, sheep producers in Bursa region can measure indoor climatic conditions such as temperature, relative humidity, and air velocity and estimate concentration level of NH_3 and CO_2 in their sheep barns and decide whether NH_3 and CO_2 concentration in their sheep barn exceed exposure limits for animal and workers' health.

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