Article

Effect of Air Heat Pump Cooling System as a Greener Energy Source on the Air Quality, Housing Environment and Growth Performance in Pig House

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Abstract: The present study examined the cooling effects of an air heat pump (AHP) system. An
AHP system was installed in a pig house to compare the effects with a traditional cooling sys-
tem on the growth performance, noxious gas emission, housing environment and consumption
of electricity. During the 19-week experimental trial, the internal temperature in the AHP cooling
system-connected pig house was significantly decreased ($p < 0.05$) than the conventional house.
Similarly, the temperature–humidity index (THI) was significantly reduced ($p < 0.05$) in the growing
and late finishing period. The carbon dioxide (CO_2) and electricity consumption were also reduced
significantly in the AHP cooling system relative to the control. The concentration of ammonia (NH_3)
during the weaning and finishing phase and the concentration of hydrogen sulfide (H_2S) during
all periods were lower in the AHP-installed pig house ($p < 0.05$). From 0–19 weeks, there was no
significant difference was observed ($p > 0.05$) in terms of the growth performance of pigs in both
houses. These results show that the AHP cooling system can be implemented as an environmentally
friendly renewable energy source in swine farms for sustainable pig production and better air quality
without adversely affecting productivity parameters.

Keywords: renewable energy source; air quality; air heat pump; noxious gas emission; electricity
consumption; pig house

1. Introduction

Effective and sustainable energy sources for the livestock and agriculture sector are
currently needed because of the limited global fossil fuel availability. The fast-growing
economic sector has increased the demand for various renewable resources, such as wind,
biogas, and photovoltaic energy against the decreasing fossil energy resources [1]. In
addition, scientists have found that CO_2 emissions to the atmosphere have increased
by 31% since the 17th century, with an annual increment of 1.5 ppm [2]. According to
Oliver et al. [3], fossil-fuel combustion is responsible for 90% of CO_2 emissions, which is
as harmful as deforestation and excessive arable land operations. Thus, implementing
renewable energy sources will facilitate sustainable energy consumption, improved energy
production, and environmental protection.

It is essential to provide optimal temperature levels in swine houses to ensure their
growth performance because they have an underdeveloped thermoregulation process [4,5].
Additionally, the pig industry's most recent challenges are enhancing the animals' growth

rate, reducing energy cost and noxious gas emissions, and improving animal and workers' welfare. A significant amount of economic cost has been allocated to the heating or cooling system of pig houses, particularly the areas associated with harsh weather conditions. The Minnesota center for farm financial management reported that approximately 5% of the production cost is utilized for electrical and fuel usage [6]. Moreover, elevated NH_3 and H_2S gas emissions adversely affect the animals' welfare, optimal growth performance, workers in the buildings, and neighbors. Similarly, particulate matter ($PM_{2.5}$) produced at farms can penetrate the respiratory organs quickly because of their small particle size and cause respiratory diseases. Furthermore, the main sources of volatile organic compounds (VOCs) emission are feed, technological devices, bedding and as well as animal. The VOCs produced due to the decomposition of animal organic substances are noxious to people and the environment or even carcinogenic [7]. Therefore, it is essential to find solutions for those problems associated with the pig housing environment and high energy consumption.

Geologically, South Korea has abundant renewable energy resource capacity. The Korean government is taking steps to increase the use of new and renewable energy from 2.1% in 2004 to 11% in 2030 [8]. Thus, examining possible renewable energy source utilization is worthwhile. Air source heat pumps (AHP) are gaining popularity these days because the ambient air is widely and freely available [9]. Air source heat pumps (AHP) and connected components can provide energy savings and storage, effectively use low-grade energy and conserve high-grade energy. In addition to energy savings., it has the potential to minimize greenhouse gas emissions [10]. By carefully reviewing all the cooling mechanism (cooling pads with fans, fogging techniques, industrial fans) in the pig farm, it is observed that the drawbacks of these methods are increased air relative humidity, formation of dust particles, and wastage of non-renewable resources [11]. Therefore, the AHP heating and cooling system can be utilized as a substitute energy source to conventional electric systems because it is an eco-friendly and sustainable source [12]. Several authors [12,13] have examined the experimental and theoretical application and effectiveness of air heat pumps. However, according to the best of our knowledge, there is no study available on the cooling effects of air heat pump systems on the housing environment and energy efficiency in pig farms. Therefore, the purpose of this article is to discuss the effects of an AHP cooling system on swine growth performance, housing conditions (H_2S, NH_3, $PM_{2.5}$, and formaldehyde), electricity consumption and economic efficiency.

2. Materials and Methods

2.1. Ethics and Animal Care

The study procedures, management, and care of pigs in the experiment followed good animal husbandry practices. The methodology was reviewed and approved by the IACUC (Institutional Animal Care & Use Committee) at Sunchon National University (SCNU IACUC-2020-09).

2.2. Experimental Period and House

The experiment was performed at the experimental farm at Sunchon National University, Republic of Korea. The effects of the AHP cooling system in a swine house were evaluated for 19 weeks (five weeks for weaning piglets; four weeks for growing pigs, and five weeks for early finishing and late-finishing pigs) in summer from 29 May 2020 to 9 October 2020.

The experimental house consisted of two separate east-facing rooms (3 m × 8 m) was subdivided into 10 pens with one pig in each pen. The room positioned in the south area of the pig house was equipped with a conventional cooling system (ventilation fans) and considered as control. The other rooms facing the north side area of the pig house were connected to the air pump cooling system (Figure 1). The outer side walls were made of plastered bricks, and the floor was made of a plastic slat to remove the slurry easily.
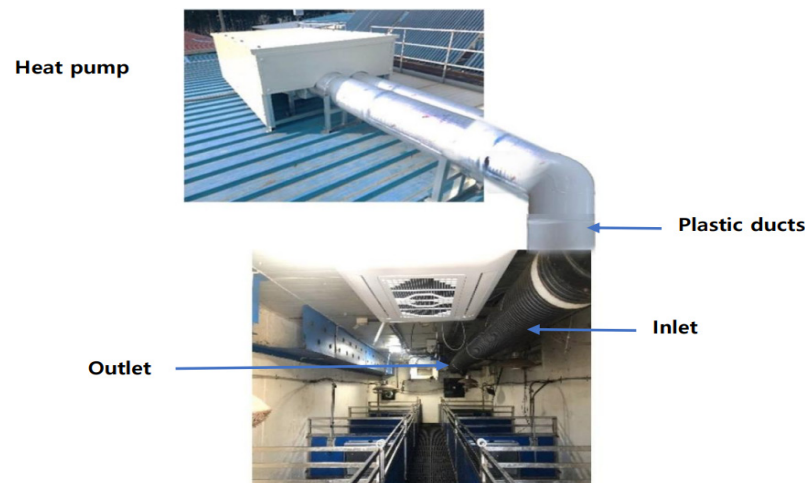
Figure 1. The schematic design of the air heat pump (AHP) cooling system [13].

The outdoor unit absorbed the heated atmospheric air and transported it to the outdoor unit of the air-conditioner. The cooled air generated from the AHP system was moved to the inside of the pig house through an internal plastic tube network with tiny pores. Ultimately, the heated liquid-vapor coolant mixture re-entered the outdoor unit to be cooled again. The inside temperature and ventilation rate were maintained automatically in the AHP cooling system-connected pig house. The ventilation rate was regulated at 75 CFM/unit for finishing pigs, 35 CFM/unit for growing pigs and 25 CFM for weaning pigs. The initial setting temperatures were similar in both swine houses according to the specific growth phases to compare fluctuations in temperature and other parameters between experimental pig houses. Moreover, all experimental animals were fed ad libitum using a commercial basal diet [14] and provided clean and fresh drinking water.

The daily electricity consumption was evaluated by installing individual electric meters in both houses (LSis, LD 1210Ra-040, Seoul, Korea). Moreover, subsequent CO_2 emissions from both houses were calculated in $kgCO_2e$ (1 kWh = 0.483 kg CO_2 equivalent) [15].

2.3. Air Heat Pump (AHP) System

The AHP system was installed and connected (BW1450M9S, LG Electronics Inc., Seoul, Korea) to the swine building at the experimental farm, as described by Jeong et al. [13]. The modified AHP system consisted of an inhale chamber, air inlet, air heat pump compressor, air-circulating pipes, and discharge chamber (Figure 2). The minimum and maximum cooling capacity of the system is 5.4 kW and 16.7 kW, respectively, and cooling power consumption is 1.1 kW and 5.8 kW, respectively.
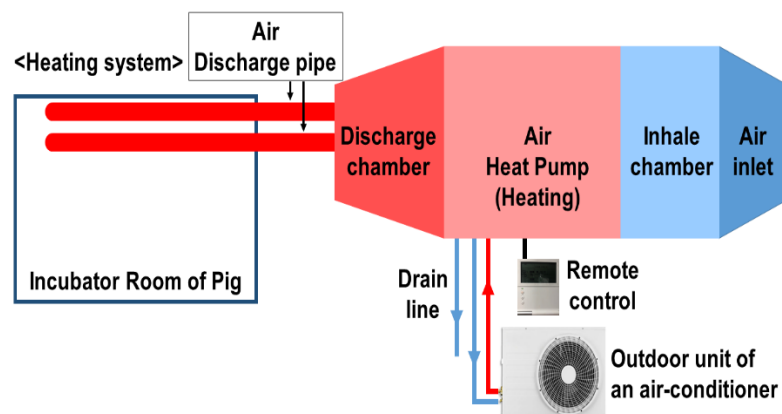

Figure 2. The outline of the air heat pump (AHP) cooling system [13].

2.4. Measurement and Analysis

The body weight gain (BWG), feed intake (FI), and feed conversion ratio (FCR) were evaluated in all growth phases of the study. The starting and finishing weights were divided by the four experimental periods to obtain the weight gain. Furthermore, the feed weight differences were evaluated every week before the weight gain measurements. The FCR was calculated as the ratio of feed intake by the average daily gain. The temperature and humidity of pig houses were measured using an SMT-75, 8-bit-smart sensor (Seoul semiconductor, Seoul, South Korea) with a range of $-20\ °C$ to $-80\ °C$.

The coefficient of performance (COP) of the AHP system was calculated by the method described by Jeong et al. [13]. The temperature–humidity index (THI) was calculated from relative humidity and temperature as an indicator of heat stress index using the following equation [16].

$$THI = 0.8T + (RH/100) \times (T - 14.3) + 46.4 \tag{1}$$

2.5. Housing Conditions Analysis

The concentration of NH_3 within the pig house was measured using a City Technology, NH_3 sensoric-3E 100 SE (City Technology, Bonn, Germany), and the concentration of H_2S was measured using an H_2S-B4 sensor (Alphasense Ltd., Great Notley, UK). Both gas sensors were established inside the two pig houses at the height of 1.9 m with a range of 0–50 ppm.

A smart air quality sensor (AR830A- Smart Sensor, Dongguan, China) with a formaldehyde range of 0–5 ppm, total volatile organic compounds (TVOCs) with a range of 0–5 ppm and a fine particulate matter ($PM_{2.5}$) range of 0–150 μg/m^3 was used to calculate the formaldehyde level, TVOCs and $PM_{2.5}$.

2.6. Statistics

The Statistical Analysis System (SAS, 2011, Version 9.3, SAS Institute, Cary, NC, USA) was used to analyze the data gathered. The Duncan's Multiple Range Test was used to calculate the growth performances, which included feed intake, final body weight, weight gain, and gain: feed ratio. A two-way *t*-test was used to assess noxious gas emissions (NH_3 and H_2S), formaldehyde levels and $PM_{2.5}$. The mean and standard error of the mean is used to describe the data (SEM). A $p < 0.05$ value was considered significant.

3. Results

3.1. Effects of the AHP Cooling System on the Growth Performance of Swine

Table 1 lists the growth performance of swine during weaning, growing, early-finishing, and late-finishing phases. There was no significant difference ($p > 0.05$) observed in any growth parameter during the weaning period (0–5 weeks). Moreover, the FCR of the control and AHP cooling system connected pig houses did not differ significantly ($p > 0.05$). However, a significant difference ($p < 0.05$) was observed in the FI during the growing and late finishing period. On average, no profound significant difference ($p > 0.05$) was found in the growth performance parameters during the 0–19 weeks' experimental period.

Table 1. Effect of the AHP cooling system on the growth performance parameters of pigs.

Parameters	Control	AHP	SEM	*p*-Value
Weaning Period (0–5 weeks)				
Initial body weight (kg)	6.18	6.16	0.37	0.9712
Final body weight (kg)	23.74	25.13	1.03	0.3902
Weight gain (kg)	17.56	18.97	0.93	0.3311
Feed intake (kg)	26.6	29.18	1.19	0.1708
FCR	1.52	1.55	0.06	0.6803

Table 1. *Cont.*

Parameters	Control	AHP	SEM	*p*-Value
Growing period (6–9 weeks)				
Initial body weight (kg)	23.74	25.13	1.03	0.3871
Final body weight (kg)	48.53	50.08	2.21	0.6432
Weight gain (kg)	24.79	24.95	1.20	0.8921
Feed intake (kg)	67.68 [a]	54.62 [b]	2.81	0.0085
FCR	2.78	2.94	0.15	0.4781
Early-finishing period (10–14 weeks)				
Initial body weight (kg)	48.53	50.08	2.21	0.6422
Final body weight (kg)	75.61	78.80	2.90	0.4793
Weight gain (kg)	27.09	28.72	1.30	0.0931
Feed intake (kg)	81.29	86.26	3.02	0.2611
FCR	3.84	3.50	0.16	0.1721
Late-finishing (5–19 weeks)				
Initial body weight (kg)	75.61	78.80	2.90	0.4791
Final body weight (kg)	108.47	113.38	3.64	0.3692
Weight gain (kg)	32.86	34.58	0.65	0.4234
Feed intake (kg)	101.16 [b]	113.24 [a]	3.91	0.0436
FCR	4.04	4.33	0.17	0.2411
Average (0–19 weeks)				
Initial body weight (kg)	6.18	6.16	0.37	0.9701
Final body weight (kg)	108.47	113.38	3.65	0.3693
Weight gain (kg)	102.29	107.22	3.55	0.3565
Feed intake (kg)	276.74	283.30	8.58	0.5991
FCR	2.55	2.64	0.05	0.2876

[a,b] Mean values with different superscripts within the same row are statistically significantly ($p < 0.05$).
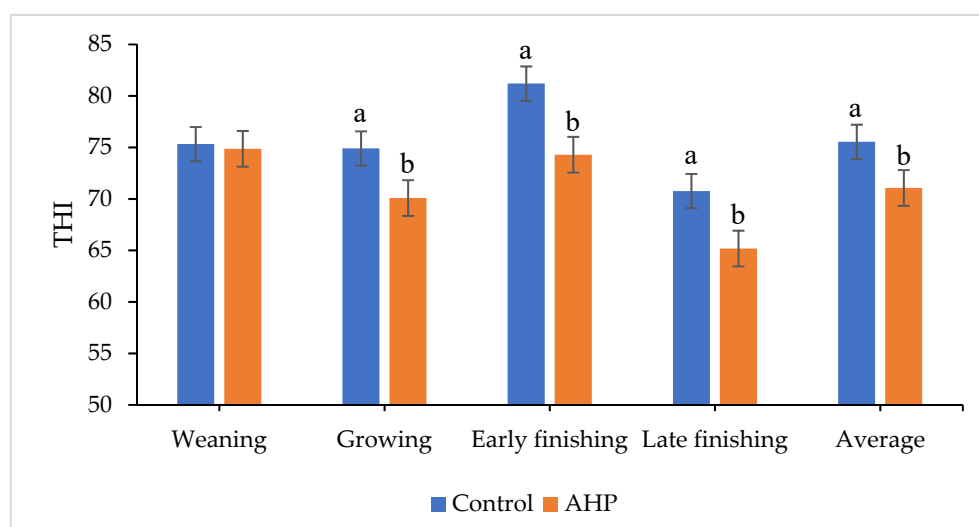
3.2. Effects of the AHP Cooling System on the Internal Housing Temperature (°C), Temperature Humidity Index (THI), and Coefficient of Performance (COP)

The temperature inside the AHP connected pig house during each period was significantly lowered ($p < 0.05$) than the outside and control pig house temperature (Table 2). On average, the temperature decreased by 22.25% in the AHP system compared to the outside temperature and 12% relative to the control house. Similarly, the THI of the AHP installed pig house was significantly reduced as compared with the control during the growing and finishing phase (Figure 3). The minimum and maximum COP calculated in this study was 3.95 for the finishing period and 4.10 for the weaning period (Table 2).

Table 2. Effect of the AHP cooling system on the inside temperature (°C) of the pig house and coefficient of performance (COP).

Growth Phase	Outside	Control	AHP	SEM	*p*-Value	Average COP
Weaning	28.70	25.85 [a]	25.01 [b]	0.21	0.0055	4.10
Growing	27.31	24.31 [a]	21.12 [b]	0.21	<0.0001	3.90
Early-finishing	31.12	27.76 [a]	23.44 [b]	0.15	<0.0001	3.98
Late-finishing	26.49	22.15 [a]	18.60 [b]	0.17	<0.0001	3.95
Average	28.40	25.03 [a]	22.02 [b]	0.22	<0.0001	3.89

[a,b] Mean values with different superscripts within the same row are statistically significant ($p < 0.05$).

Figure 3. Effect of the AHP cooling system on the temperature–humidity index (THI). Data are presented as mean ± SEM. [a,b] Values with different superscripts within the same bars differ significantly ($p < 0.05$).

3.3. Effects of the AHP Cooling System on the NH_3 (ppm) and H_2S (ppm) Concentration inside the Swine House

Table 3 shows the NH_3 concentration during the 19-week experimental period as affected by the AHP cooling system. The data shows that during the weaning and early finishing phases, the NH_3 emissions decreased significantly ($p < 0.05$) in the AHP cooling system-connected pig house than the conventional cooling system. Conversely, the H_2S emissions were reduced significantly ($p < 0.05$) in the AHP cooling system during the weaning, growing, and finishing phases. However, H_2S emissions in the AHP-connected pig house were unaffected ($p > 0.05$). On average, the H_2S emissions decreased significantly in the AHP-connected pig house ($p < 0.05$) during the entire experiment period (0–19 weeks). The TVOC concentration was not affected ($p < 0.05$) by the AHP except for the growing phase (Table 3).

Table 3. Effects of the AHP cooling system on NH_3 (ppm) and H_2S (ppm) concentrations in the pig house.

| Growth Phase	Control	AHP	SEM	*p*-value
Ammonia (NH$_3$ ppm)				
Weaning	2.54 [a]	2.25 [b]	0.09	0.0190
Growing	1.50	1.34	0.06	0.0710
Early-finishing	1.46 [a]	1.18 [b]	0.09	0.0470
Late-finishing	1.27 [b]	1.69 [a]	0.06	0.0001
Average	1.71	1.63	0.05	0.3500
Hydrogen sulfide (H$_2$S ppm)				
Weaning	0.01 [a]	0.00 [b]	0.02	0.0002
Growing	0.01 [a]	0.00 [b]	0.01	0.0318
Early-finishing	0.01	0.01	0.01	0.4147
Late-finishing	0.02 [a]	0.00 [b]	0.01	0.0318
Average	0.01 [a]	0.00 [b]	0.02	0.0201
Total volatile organic compounds (TVOC ppm)				
Weaning	0.14	0.12	0.11	0.0170
Growing	0.18 [a]	0.13 [b]	0.17	0.0047
Early-finishing	0.13	0.12	0.08	0.2500
Late-finishing	0.14	0.11	0.04	0.1610
Average	0.15	0.12	0.10	0.1781

[a,b] Mean values with different superscripts within the same row are statistically significant ($p < 0.05$).
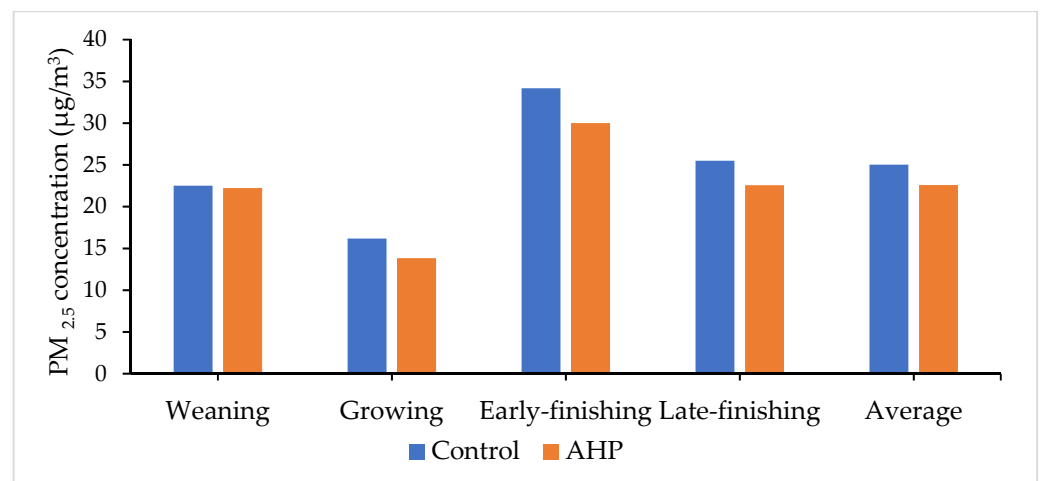
3.4. Effects of the AHP Cooling System on Total Volatile Organic Compounds, Formaldehyde, and Particulate Matter inside the Swine House

Figure 4 presents the effects of the AHP cooling system on the formaldehyde (ppm) concentration inside the pig house during the different growth phases. The formaldehyde concentration in the AHP cooling system connected pig house reduced significantly ($p < 0.05$) in the weaning and late finishing periods. Additionally, no significant difference was observed in both treatments during the early finishing and growing periods ($p > 0.05$). The $PM_{2.5}$ concentration was comparable ($p > 0.05$) in both treatments during all growth phases (Figure 5). Although there was no significant difference, it was observed that numerical levels of the $PM_{2.5}$ reduced in the AHP-connected pig house than in the control treatment.
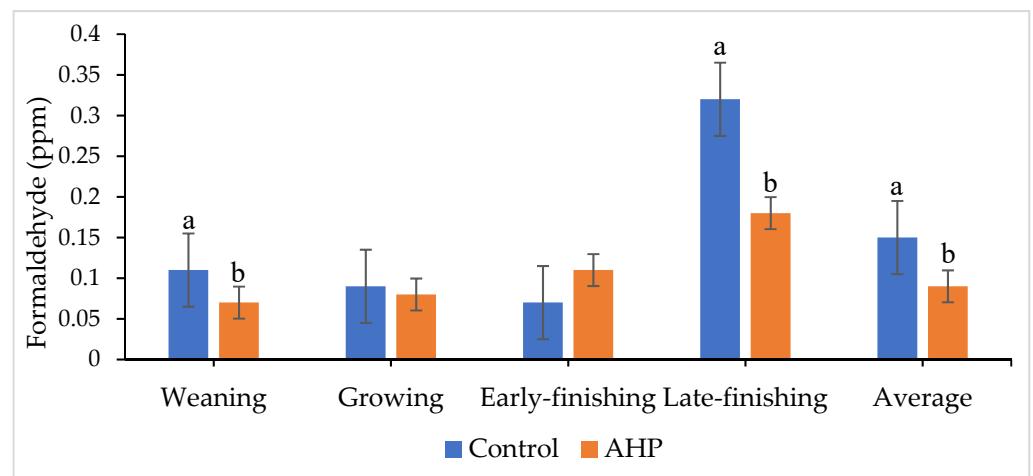
Figure 4. Effect of the AHP cooling system on the formaldehyde (ppm) concentration in the pig house. Data are presented as mean ± SEM. [a,b] Values with different superscripts within the same bars differ significantly ($p < 0.05$).

Figure 5. Effect of the AHP cooling system on the fine particulate matter ($\mu g/m^3$) concentration in the pig house. Data are presented as mean ± SEM.

3.5. Effects of AHP Cooling System on the Energy Utilization and CO_2 Emissions

The data show that regardless of the growth phases, the pig house's energy consumption and CO_2 emission connected with the AHP cooling system was reduced than the control (Table 4). On average, the energy consumption and CO_2 emission were decreased by 12% in the AHP-connected pig house compared to the control.

Table 4. Effects of the AHP cooling system on the energy utilization (kWh) and CO_2 emissions (kg) in the pig house.

Growth Phase (Weeks)	Energy Consumption (kWh)		CO₂ Emission (kg)	
	Control	AHP	Control	AHP
Weaning				
1st week	214.75	134.70	103.72	65.06
2nd week	117.10	69.90	56.56	33.76
3rd week	112.70	103.05	54.43	49.77
4th week	62.30	92.60	30.09	44.73
5th week	61.65	80.48	29.78	38.87
Average	113.70	96.15	54.92	46.44
Growing				
1st week	46.60	41.25	22.51	19.92
2nd week	49.30	36.30	23.81	17.53
3rd week	60.05	57.25	29.00	27.65
4th week	63.60	71.20	30.72	34.39
Average	54.89	51.50	26.51	24.87
Finishing				
1st week	60.70	49.45	29.32	23.88
2nd week	61.30	45.60	29.61	22.02
3rd week	52.60	55.10	25.41	26.61
4th week	77.90	66.93	37.63	32.32
5th week	25.80	29.95	12.46	14.47
Average	55.66	49.41	26.88	23.86
Total	1066.35	933.75	515.05	451.00

4. Discussion

Temperature and relative humidity are some of the most important parameters for the evaluation of pig house environments in mechanically ventilated and closed insulated buildings [17]. A slight fluctuation in these parameters can cause cold shock or heat stress in pigs. Pigs are more prone to heat stress in hot weather as they lack a proper panting system and a large deposit of subcutaneous fat under their skin [4]. In addition, Licharz et al. [18] reported that pig housing must have access to a comfortable indoor temperature to comply with animal welfare legislation. The inside temperature of the AHP connected pig house remained at a lower level during the entire experiment. These findings might be attributed to the equal distribution of the AHP cooling system inside the pig house due to its higher COP value and lower running period [13]. As the pigs get older, their optimum temperature decreases and they feel the detrimental effects of the heat stress at a relatively low temperature as compared with the weaning piglets. In the present study, the cooling mechanism of the AHP system significantly reduced the inside temperature up to 18 °C during the late finishing period. These results are in agreement with the findings of Adebiyi et al. [16] that the optimum temperature for finishing pigs is below 20 °C. THI is used as a basis for the safety index to explain the categories of the heat stress due to high temperatures for livestock. It is reported by Myer and Bucklin [19] that only humidity itself is not harmful for swine production unless the high temperature is combined with high humidity. According to the National Atmospheric and Oceanic administration [20], THI $\geq$ 84 is considered an emergency, THI $\leq$ 74 is safe and 74 < THI < 79 is classified as an alert. In the present study, the temperature–humidity index for all phases of swine growth falls in the safety zone. This might be due to the better cooling performance of the AHP system in extremely hot and humid conditions.

In this study, no significant differences were observed in the average growth performance of swine from 0–19 weeks. Although not significant, the pigs raised in the AHP cooling system connected pig house exhibited a numerical increase in the final body weight

and feed intake. Similarly, Jeong et al. [13] reported that the utilization of the AHP system in the pig house did not significantly influence the body weight gain and feed conversion ratio. The first study regarding the AHP system in a swine building was conducted by Riva et al. [21], who reported an improved feed intake, weight gain and feed conversion ratio in the AHP connected house as compared to the house connected to the LPG gas system. The reduced growth performance might be due to the elevated fume concentration in the LPG gas system-operating pig house. In short, using the AHP cooling system inside the pig house prevents the animals from heat stress without harming animal production and health, especially in modern genetic lines [11,22]. Hence, utilizing the AHP system-based energy distribution pattern is essential for housing schemes to keep sows and piglets at optimal temperatures [23].

The permissible level of NH_3 recommended by the International Commission of Agricultural and Bio-Systems Engineering (CIGR) is 20 ppm [24]. Generally, NH_3 concentration in the swine farm range between 0 to 40 ppm, and H_2S concentration is usually less than 2 ppm [25]. The NH_3 emissions in this experiment were significantly reduced in the AHP cooling system connected pig house. The lower noxious gas emission in the AHP cooling system might be due to the increased fresh air moving into the pig house. Another reason for the lower NH_3 concentration is the absorption of ammonia by the condenser. Riva et al. [21] also observed a large amount of damp dust rich in ammonia nitrogen on the exchanger. The recent findings confirm with the previous reports that the level of NH_3 emission may increase in intensive livestock houses due to the higher temperature fluctuations [26,27]. Similarly, the average effect of the AHP cooling system in H_2S emission was significantly reduced than the recommended threshold levels. Hence, implementing an AHP cooling system is a practical and sustainable step in the intensive swine industry. Another critical aspect of swine building is associated with the concentration of particulate matter. $PM_{2.5}$ has become a critical public health concern in some countries, and its major cause is the burning of fossil fuels. In this study, $PM_{2.5}$ ($\mu g/m^3$) was numerically lower in the AHP cooling system connected pig house relative to the conventional pig house. These findings are supported by Jeong et al. [13] that AHP can reduce $PM_{2.5}$, as there is no emission from the AHP system due to the burning of fossil fuels. On the other hand, the levels of formaldehyde during weaning and late finishing growth stages of swine are significantly lower than in the conventional pig house. This could be ascribed to the AHP pig house's optimum air circulation. However, the relationship between formaldehyde levels, $PM_{2.5}$ concentrations, and AHP system installation is unclear. As a result, further research in future is needed to determine the impact of $PM_{2.5}$ and formaldehyde on the use of renewable energy sources.

Renewable energy sources are gaining popularity in the livestock sector because they can reduce electricity consumption and are environmentally friendly. Additionally, in the present study, the AHP system decreased the consumption of electricity and CO_2 emission in the pig house as compared to the conventional cooling system. These results are in agreement with a study conducted by Rabczak et al. [28] that the AHP system inside the large-scale buildings reduced the release of CO_2 into the atmosphere by 40%. Similarly, in our previous study using the same AHP during the heating phase, the electricity consumption was decreased by 63% [13]. Furthermore, many studies [9,29,30] have reported that energy consumption and greenhouse gas emissions were reduced by replacing an existing heating and cooling systems with heat pumps for animal farms and residential buildings. The coefficient of performance (COP) is used to estimate the performance index and efficiency of the AHP system. The average COP calculated in this study was 3.89 for a duration of 19-weeks. Similar to our findings, Jeong et al. [11] reported that the electricity consumption was significantly decreased in the AHP connected pig house due to the high COP value. A better COP value might help the AHP system to distribute uniform cool air inside the pig house.

5. Conclusions

1. The implementation of the AHP cooling system could enhance the housing environment without adverse effects on the pig production traits.
2. The AHP cooling system resulted in a lower concentration of NH_3 inside the pig house.
3. Despite the high installation cost, the government should provide subsidies to commercial swine farmers for sustainable pig production and environmental protection.
4. The AHP system can easily be installed, and its service lifetime lasts for more than 20 years with little maintenance.
5. Considering cooling effects and energy savings, the AHP system can be implemented in commercial swine farms as an innovative, eco-friendly and greener energy source.

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Institutional Review Board Statement: The methodology was reviewed and approved by the IACUC (Institutional Animal Care & Use Committee) at Sunchon National University (SCNU IACUC-2020-09).

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors have no conflict of interest.

Nomenclature

AHP	Air heat pump
THI	Temperature–humidity index
CO_2	Carbon dioxide
NH_3	Ammonia
H_2S	Hydrogen sulfide
IACUC	Institutional Animal Care & Use Committee
CFM	Cubic feet per minute
kWh	kilowatt hour
kW	kilowatt
COP	Coefficient of performance
$PM_{2.5}$	Particulate matter
TVOCs	Total volatile organic compounds
SAS	Statistical analysis system
SEM	Standard error of the mean
BWG	Body weight gain
FI	Feed intake
FCR	Feed conversion ratio
CIGR	International Commission of Agricultural and Bio-Systems Engineering

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