Research Article

Solar Based Incubator as Renewable Source of Energy on the Growth Performance, Electricity Uses and Housing Environments of Piglets

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Abstract | This study examined the effects of solar heating system as a source of renewable energy on the growth performance, electricity uses and housing environments of piglets. For this trial, a total 20 piglets having similar average body weight 6.83 ± 1.07 kg (mean ± std.) were randomly divided into 2 (two) incubators, control (conventional) incubator and the solar based incubator with 10 replicates each. The experimental duration was 10 weeks (70 days). Feed intake, body weight gain, electricity consumption, environmental parameters includes temperature, humidity, ammonia and hydrogen sulfide concentration were measured on weekly basis. There were no significant differences on the final body weight, average daily body weight gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR), between the incubators. However, ADG was numerically higher ($P > 0.05$) and FCR was lower ($P > 0.05$) in solar heating incubator compared with the control incubator. The consumption of electricity with solar based incubator was reduced by 59.13 kWh/head and the saving efficacy was about 49.6% than the conventional incubator. Internal temperature was higher ($P < 0.05$) in solar based incubator. The ammonia concentration and hydrogen sulfide concentration were significantly lower ($P < 0.05$) in solar based incubator than the control incubator. The solar based heating incubator might be eco-friendly and renewable source of energy for the sustainable pig production.

Keywords | Solar based incubator, Growth performance, Electricity uses, House environment, Piglets

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INTRODUCTION

A sustainable source of energy is important for the livestock and agricultural sector while the natural fuel is limited (Rathnayake et al., 2021). The continue uses of fossil fuel has led a higher energy prices in the worldwide (Nakomcic-Smaragdakis et al., 2012). In addition, CO_2 emissions from the fuel is increasing with an annual incrememt of 1.5 ppm (Apak, 2007). Fossil-fuel contributes about 90% of CO2 emissions, that causes the deforestation, and pollute the environment (Oliver et al., 2012). Thus, identifying the renewable sources of energy to protect the environmental is essential. The application of renewable energy sources in agriculture, is increasing globally for it's sustainable nature, high production performance with low maintaining cost (Choi et al., 2012). The government of Republic of Korea, decided to rise the application of renewable energy from 6% to 11% from 2021 to 2030 (Lee et al., 2009; Lola and Graham, 2021). It is important to ensure the optimal housing environment includes temperature, humidity, carbon dioxide, ammonia, hydrogen sulfide levels in swine houses for optimum growth and feed intake especially in weaning period. As weaning is the most critical period to expose stress to piglets due to environmental changes, feed, and in the thermoregulation process (Renaudeau et al., 2011; Long et al., 2021). Housing environment can play a role to minimize the concentration of NH3, H2S and CO2, emission from animal farm (Rodriguez et al., 2020; Saha et al., 2010). Now, it's time to consider animal housing aimed to enhance energy efficiency by applying renewable energy sources. Solar energy is the largest and cheapest energy resource on the earth (Tariq et al., 2021). Application of solar energy in rural life is well known since few years. Now, solar technology has also been developed in agricultural process, for example irrigation, green house, poultry and livestock farming. Solar energy is the most renewable energy resource in the world for its availability with many advantages (Acosta-Silva et al., 2019). The Sun produces energy at a rate of 3.8×1023 kW, of which approximately 1.8×1014 kW is seized by the earth which ensured the availability of solar energy for thermal applications (Paternoster et al., 2015). However, information about the application of solar based energy on the production performance and housing environment of piglets are not available.

Taking consideration, this study was focused on the uses of solar based incubator as a source of renewable energy on the growth performance, electricity uses and housing environment of piglets compared with conventional incubator.

MATERIALS AND METHODS

Animals And Experimental Design

This research was conducted at the experimental swine farm of Sunchon National University, the Republic of Korea. The animals care procedure was approved by the review committee of the Animal Use and Care Council of the university. The trial was performed from 13th August 2021 to 22nd October 2021 (10 weeks). Considering the average body weight 6.83 ± 1.07 kg (mean ± std.), a total of 20 piglets [(Duroc) x (Landrace White x Yorkshire)] were randomly divided into two separated incubators while every house has ten individual pens as replication. The control incubator pens were heated by using 600 W heating lamps while the other room was designed by installing a solar heat pump. Piglets were fed on corn soybean meal based diets (data not presented).

Growth Performance

At beginning and at the end of the trial, the weight of the individual piglet was considered as initial and final body weight (kg). The average daily body weight gain was calculated by subtracting the initial weight from the final weight and divided with experimental period. The feed was offered twice daily and feed intake was considered by subtracting the remaining feed from the supplied feed. The feed conversion ratio (FCR) was calculated by dividing the feed intake by the weight gain.

Electricity And Housing Environment

The electricity consumption inside the solar incubator and the control incubator were measured by two individual smart energy electrical sub-meters. Temperature and humidity of incubators were measured by sensors with thermocouples and thermistors. The range for temperature and humidity were -2ºC to 80ºC and 0-100% respectively that were linked with data logger (CR10X Data Logger, Edmonton, Canada) (Mun et al., 2020). The concentration for ammonia and hydrogen sulfide were measured by using a NH3 sensor 3E 100 SE (Bonn, Germany) and using a H2S-B4 sensor (Alphasense Ltd., Great Notley, UK), respectively (Mun et al., 2020). The range of sensors were between 0-50 ppm.

Statistical Analysis

The trail data were examined with one-way analysis of variance (ANOVA) by SPSS (2006). Individual pig was the replication unit. Duncan's multiple range test was used to assessed the differences between means. The results were presented in table as mean ± SEM with the significant level at $P < 0.05$.

RESULTS AND DISCUSSION

Growth Performance

The effect of solar based incubator on feed intake, body weight gain, and feed conversion ratio (FCR) were shown in Table 1. During the entire experimental period, no significant differences ($P > 0.05$) were noted on the feed intake, final body weight, average daily gain (ADG) and FCR. However, ADG was numerically higher ($P > 0.05$) in solar based incubator than the control incubator. FCR was lower ($P > 0.05$) in solar based incubator than conventional control incubator although it was not significant. Daily weight gain, feed intake as well as FCR are the most important indicators for economy swine production. Adaptation of the new technology in farming system, pro

Table 1: Effects of solar based incubator on growth performance of piglets

Parameters	Control incubator	Solar based incubator	SEM	*P* value
Initial body weight (kg)	6.83	6.83	0.24	0.994
Final body weight (kg)	43.66	44.50	0.83	0.624
Average daily gain (g)	526	538	12.05	0.628
Average daily feed intake (g)	1044	1021	5.94	0.405
Feed conversion ratio (FCR)	1.98	1.90	0.06	0.325

n=10

SEM, pooled standard error of the means.

Level of significant ($P < 0.05$)

Table 2: Effects of solar based incubator on electricity uses

Parameters	Control incubator	Solar based incubator
Total uses (kWh/10 weeks)	1192.92	601.57
Average uses (kWh/head)	119.29	60.16
Compared with control incubator		
Reduced electricity consumption (kWh/10weeks/head)	-	59.13
Saving efficacy %	-	49.60

Table 3: Effects of solar based incubator on environment of pig house

Parameters	Control incubator	Solar based incubator	SEM	*P* value
Internal temperature (°C)	24.68	26.45	1.79	0.035
Internal humidity %	84.19	70.86	3.24	0.725
Ammonia (ppm)	1.88	0.83	0.35	0.042
Hydrogen sulfide (ppm)	0.14	0.01	0.01	0.002
Outside environment				
Temperature (°C)	24.79			
Humidity %	91.10			
Wind speed (m/s)	0.66			
Solar radiation (w/m^2)	197.95			

Level of significant ($P < 0.05$)

duction performance must be in consideration (Kim et al., 2005). Using solar heating system in the piglet's incubator, had no any adverse effects on the growth performance of piglets in the current study, indeed had a positive effect on the daily gain and FCR, those were in line with the previous studies with an air heat pump and geothermal heat pump system of the pig house respectively (Choi et al., 2010; Jeong et al., 2020).

Electricity Consumption

The electricity consumption of pig house was shown in Table 2. The average electricity consumption was lower in solar based incubator than the control incubator. Compared with control incubator, the reduced energy consumption (electricity) was 59.13 kWh/10weeks/head and the energy saving efficiency was 49.60% respectively. The higher energy saving efficacy in solar based incubator may due to uniform heat distribution with less operating hours by using sunlight. In a previous report with the geothermal heating system that can provide three units of electricity per unit of consumption resulting in lower electricity consumption than the conventional heating system (Charoenvisal, 2008). In addition, the cost of electricity can be reduced by applying the geothermal heating system in livestock farms (Barbier, 2002; Mun et al., 2020). Wu (2009), reported that the electricity consumption cost can be reduced by about 46% with air source heating system than the conventional heating system. The price of fossil fuels is increasing continuously. Therefore, the renewable energy should be applied for the sustainable livestock farming.

Housing Environment

The effects of solar based incubator on housing environment of piglets was shown in Table 3. According to the Table 3, internal temperature of solar based incubator was higher ($P < 0.05$) than the control incubator. In addition, ammonia (ppm) and hydrogen sulfide (ppm) concentration were lower ($P < 0.05$) in solar based incubator than the conventional control incubator. However, no significant differences were found on humidity between the incubators. The house inside temperature is an important environmental parameter for good health and production performance of swine (Rathnayake et al., 2021). Any variation of pig house temperature may negatively effect on the growth of pigs (Hessel et al., 2010). Piglets are usually susceptible to the cold stress, especially in weaning period. In this study, the solar based heating pump converted the heat from sunlight effectively to the pig barn that ensured the uniform temperature inside the pig barn. The higher temperature showed the efficiency of the solar based incubator system which can provide enough heat to maintain the required optimum temperature for piglets. The optimum temperature for first week of weaned piglets are 28 ^{o}C, however the temperature should be reduced by 2 ^{o}C for the next week and maintained at 26^{o}C, which was within the range of our current findings (Close and Stanier, 1984). Ammonia and hydrogen sulfide gas are harmful gases to human health and animals. The emission of ammonia and hydrogen sulfide as harmful gases from swine farm might have negative effects on pig's growth, health and welfare (Mun et al., 2022). The tolerate level of ammonia (NH3) is 20 ppm (Soren and Krister, 2002) according to international commission of agriculture and Bio-System engineering. The growth rate of pigs may fall up to 30% with the increased level of NH3 in pig house (Mun et al., 2022). The level for H2S in the swine farm should be less than 2 ppm (Ni et al., 2017). In this study, both the ammonia and hydrogen sulfide level were significantly lower in solar based incubator system than the conventional incubator which support the numerical higher daily weight gain in solar based incubator. Lower harmful gases inside the solar based incubator, may due to the passes of fresh air in the solar based pig's incubator. The entry of fresh air may have a role to minimize or dilutes the ammonia and hydrogen sulfide gases (Choi et al., 2010). Saha et al. (2010) also reported that installing a pit ventilation system could improve the air quality and reduce the ammonia level about 37-53% from pig house. The concentration of NH_3 was reduced by about 30% in the geothermal heating system at pig house (Jacobson, 2012). In addition, fuel combustion was not associated with the solar based incubator system which may another reason of reducing the harmful gases in the pig house. Furthermore, Solar heating pump system is known as greener and renewable energy source which can play role on the energy security, and can reduce the climate changes. Therefore, the application of solar energy can be the effective solutions for those problems associated with high odor gas emission in the pig house and energy consumption.

CONCLUSION

The uses of the solar based incubator system could improve the house temperature, and could reduce the electricity uses, odor gas concentration in pig house without affecting the optimum growth performance of piglets. Considering the favorable role for the environment, the solar based incubator system can be useful as a renewable source of energy for sustainable pig production.

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NOVELTY STATEMENT

The importance of renewable and environment friendly solar energy source for modern swine farming have been described in this study based on its lower electricity cost, improve house environment and piglet's growth performance.

CONFLICT OF INTEREST

The authors claim that they have no competing interest.

AUTHORS CONTRIBUTION

All authors contributed equally in the planning of this study, conducting research, and drafting the manuscript. All of them approved the final version of the article.

REFERENCES

Acosta-Silva YJ, Torres-Pacheco I, Matsumoto Y, Toledano-Ayala M, Soto-Zarazua GM, Zelaya-Angel O, Mendez-Lopez A (2019). Applications of solar and wind renewable energy in agriculture: A review. Sci. Prog., 102:127-140. https://doi.org/10.1177/0036850419832696

Apak R (2007). Alternative solution to global warming arising from CO2 emissions partial neutralization of tropospheric H2CO3 with NH3. Environ. Prog., 26:355-359. https://doi.org/10.1002/ep.10228

Barbier E (2002). Geothermal energy technology and current status: An overview. Renew. Sustain. Energy Rev. 6:3-65. https://doi.org/10.1016/S1364-0321(02)00002-3

Charoenvisal K (2008). Energy performance and economic evaluations of the geothermal heat pump system used in the knowledge works i and ii buildings, Blacksburg, Virginia. Master's Thesis, Virginia Polytechnic Institute and State

University, Blacksburg, VA, USA.

Choi H, Park J, Song J, Na J, Kim M, Bang H, Kang H, Park S, Chae H, Suh O (2010). Evaluation on heating effects of geothermal heat pump system in farrowing house. J. Livest. Housing Environ., 16:205-215.

Choi HC, Salim HM, Akter N, Na JC, Kang HK, Kim MJ, Kim DW, Bang HT, Chae HS, Suh OS (2012). Effect of heating system using a geothermal heat pump on the production performance and housing environment of broiler chickens. Poult. Sci., 91:275-281. https://doi.org/10.3382/ps.2011-01666

Close WH, Stanier MW (1984). Effects of plane of nutrition and environmental temperature on the growth and development of the early weaned piglet- Energy metabolism. Anim.Prod., 38:221-231. https://doi.org/10.1017/S000335610000221X

Hessel EF, Zurhake C (2010). Heating and cooling performance of an under floor earth tube air tempering system in a mechanical ventilated farrowing house. In Proceedings of the XVII World Congress of the International Commission of Agricultural and Bio Systems Engineering (CIGR), Quebec, QC, Canada, 13-17 June 2010.

Jacobson L (2012). Pig housing systems designed to manage or adapt to climate change impacts. In Proceedings of the Allen D. Leman Swine Conference, St. Paul, MI, USA, 15-18 September 2012.

Jeong M, Rathnayake D, Mun H, Dilawar M, Park K, Lee S, Yang C (2020). Effect of a sustainable air heat pump system on energy efficiency, housing environment, and productivity traits in a pig farm. Sustainability., 12: 9772. https://doi.org/10.3390/su12229772

Kim Y, Kim S, Weaver M, Lee C (2005). Increasing the pig market weight: world trends, expected consequences and practical considerations. Asian-Australas. J. Anim. Sci., 590-600. https://doi.org/10.5713/ajas.2005.590

Lee J (2009). Current status of ground source heat pumps in Korea. Renewable and Sustainable Energy Reviews., 13:1560-1568. https://doi.org/10.1016/j.rser.2008.10.005

Lola A, Graham E (2021). Ember global electricity review, South Korea 2021. https://ember-climate.org/insights/research/global-electricity-review-2021.

Long S, He T, Kim SW, Shang Q, Kiros T, Mahfuz SU, Wang C, Piao X (2021). Live yeast or live yeast combined with zinc oxide enhanced growth performance, antioxidative capacity, immunoglobulins and gut health in nursery pigs. Animals., 11:1626. https://doi.org/10.3390/ani11061626

Mun HS, Dilawar MA, Jeong MG, Rathnayake D, Won JS, Park KW, Lee SR, Ryu SB, Yang CJ (2020). Effect of a heating system using a ground source geothermal heat pump on production performance, energy-saving and housing environment of pigs. Animals., 10: 2075. https://doi.org/10.3390/ani10112075

Mun HS, Dilawar MA, Kim C, Ryu SB, Moon J, Yang CJ (2022). Geothermal heat pump as an environmental friendly, renewable energy source for sustainable pig production. Environ. Asia., 15(1):166-173.

Nakomcic-Smaragdakis B, Stajic T, Cepic Z, Djuric S (2012). Geothermal energy potentials in the province of Vojvodina from the aspect of the direct energy utilization. Renewable and Sustainable Energy Reviews., 16:5696-5706. https://doi.org/10.1016/j.rser.2012.05.038

Ni J, Heber A, Lim T (2017). Ammonia and hydrogen sulfide in swine production. In Air Quality and Livestock Farming; CRC Press: Boca Raton, FL, USA; 2017. https://doi.org/10.1201/9781315738338-3

Olivier J, Janssens-Maenhout G, Peters J (2012). Trends in Global CO2 Emissions: 2012 Report; EUR 25388 EN; PBL Netherlands, Environmental Assessment Agency, Publications Office of the European Union: The Hague, The Netherlands, 2012; p. 40.

Paternoste G, Zanuccoli M, Bellutti P, Ferrario L, Ficorella F, Fiegna C, Magnone P, Mattedi F, Sangiorgi E (2015). Fabrication, characterization and modeling of a silicon solar cell optimized for concentrated photovoltaic applications. Solar Energy Materials and Solar Cells.,134: 407-416. https://doi.org/10.1016/j.solmat.2014.12.026

Rathnayake D, Mun HS, Dilawar MA, Chung IB, Park KW, Lee SR, Yang CJ (2021). Effect of air heat pump cooling system as a greener energy source on the air quality, housing environment and growth performance in pig house. Atmosphere., 12:1474. https://doi.org/10.3390/atmos12111474

Renaudeau D, Gourdine JL, Pierre NR (2011). A meta-analysis of the effects of high ambient temperature on growth performance of growing-finishing pigs. J. Anim. Sci., 89:2220-2230. https://doi.org/10.2527/jas.2010-3329

Rodriguez MR, Losada E, Besteiro R, Arango T, Velo R, Ortega JA, Fernandez MD (2020). Evolution of NH3 concentrations in weaner pig buildings based on setpoint temperature. Agronomy.,10:107. https://doi.org/10.3390/agronomy10010107

Saha CK, Zhang G, Kai P, Bjerg B (2010). Effects of a partial pit ventilation system on indoor air quality and ammonia emission from a fattening pig room. Biosys. Engineer., 105:279-287. https://doi.org/10.1016/j.biosystemseng.2009.11.006

Soren P, Krister S (2002). International commission of agricultural and biosystems Engineering, 4th ed.; Research Centre Bygholm, Danish Institute of Agricultural Sciences: Horsens, Denmark, 2002. p. 75-92.

SPSS (2006). Statistical software package for the social sciences SPSS Inc., IL. 20.0.

Tariq G, Ashraf M, Hasnain U (2021). Solar technologfy in agriculture. Technology in Agriculture; Edited by Fiaz Ahmad and Muhammad Sultan, Intech Open, London, UK. 10.5772/intechopen.98266.

Wu R (2009). Energy efficiency technologies-air source heat pump vs. ground source heat pump. J. Sustainable Develop.,14-23. https://doi.org/10.5539/jsd.v2n2p14