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Impact of climate change on pig production — adaptation and mitigation strategies

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This article narrates different effects of climate change on growth, feed intake, carcass yield besides contribution of pig to GHG production. It was reported that increasing ambient temperature from 22 to 29 °C resulted in 15 % reduction in average daily feed intake and 13 % reduction in average daily gain, *i.e.*, growth in crossbred pigs. Ambient temperature range of 18 to 21 °C was found to support optimal productive performance of growing to finishing pigs as they have a limited capacity to lose heat by cutaneous evaporative loss, *i.e.*, sweating. Even heat stress had adverse effect on digestive function and reproductive performances of pigs. Methane, carbon dioxide and ammonia are released from pig slurry and found present in pig houses. Different measures for adaptation and mitigation were discussed also. Scientific housing with proper orientation, ventilation, provision of sufficient floor space, painting of roof by white paint, use of false ceiling were very much beneficial for the comfort of pig. Implementation of cooling arrangement in the shed would reduce heat stress. Scheduling most of the activities in early morning, late afternoon and practice of night grazing was advisable. Provision of low fiber, energy rich diet and cold clean drinking water to pigs were very essential to overcome adverse effect of heat stress on feeding, productive and reproductive performances. Use of anti-oxidants, feed additive, ensiling of fodder, scientific manure management, reducing unproductive pigs and use of indigenous breeds were some of the mitigation measures.

Keywords: pigs, climate change, heat stress, adaptation, mitigation

Introduction

As per 20th Livestock Census [1] the population of pig in India is 9.06 m which is 12 % lesser than earlier livestock census, 2012. State wise Assam (2.10 m) ranks first in pig population followed by Jharhhand (1.28 m), Meghalaya (0.71 m), West Bengal (0.54 m) and Chattisgarh (0.53 m). Mostly exotic breeds such as Yorkshire, Landrace, Duroc, Hampshire and their crosser are reared besides indigenous and nondescript pigs. In India less attention is being paid for animal housing and hence we find that housing for animals are constructed without proper planning and designing. The basic reason for housing of pig is that it should modify the microenvironment of pigs for reducing heat stress elicited due to climate change.

Pigs are homoeothermic animals that maintain their core body temperature within a relatively narrow physiological range to sustain normal health and productivity. Exposure to ambient temperature beyond the thermoneutral zone (TNZ) either above or below its limit can induce thermal stress and adversely affects growth, production, reproduction and overall health. In tropical and subtropical regions, upper critical temperature is particularly important as pigs are highly susceptible to elevated environmental temperature. The upper critical temperature is generally lower in exotic breeds and their crosses than indigenous breeds. The thermoneutral zone (TNZ) for pig was reported to range from 10 to 21 °C [11]. The micro environment experienced by pigs is influenced by several factors such as air temperature, relative humidity, air velocity and solar radiation. The combined effects of temperature and humidity can be expressed through the temperature-humidity index (THI), which is commonly used to evaluate the severity of heat stress in pig. In pig house, a THI value of 80 or below is generally considered a normal condition, whereas values of 81–85, 86–90, and above 90 correspond to alert, danger, and emergency conditions, respectively. The Livestock Weather Safety Index (LWSI), developed by the United States Weather Bureau, provides a useful approach for assessing the combined effects of air temperature and relative humidity on livestock. However, the conventional THI-based LWSI does not account for other important environmental variables, such as solar radiation and wind speed, which can also substantially influence the actual thermal load experienced by pigs [33].

Heat stress becomes more severe when high ambient temperature is accompanied by elevated relative humidity, inadequate air movement, and intense solar radiation. Under such conditions, pigs activate physiological mechanisms to dissipate excess body heat, primarily through increased respiration and panting. When these mechanisms are insufficient to maintain thermal balance, body temperature rises, resulting in physiological and metabolic disturbances. Heat stress can suppress feed intake through effects on hypothalamic regulation of appetite, thereby reducing nutrient availability for productive functions. Consequently, prolonged exposure to high temperatures may impair growth, meat production, and reproductive performance.

The capacity of pigs to tolerate heat varies according to age, nutritional status, hydration, production level, and degree of acclimatization. Young animals, poorly fed or dehydrated pigs, highly productive animals, and those not acclimatized to high temperatures are generally more vulnerable to heat stress. Prolonged exposure to elevated ambient temperatures increases the physiological effort required to limit endogenous heat production and maintain thermal homeostasis. Such heat stress may also interfere with reproductive processes, including disruption of the normal estrous cycle [38].

Impact of Climate Change on Pig Production

The domestic pig shows no morphological adaptation to maintain a constant body temperature in response to rapid changes occurring in the environment. Compared to other species of farm animals, the pig is very sensitive to elevated temperature because of non-functional sweat glands and thus, does not facilitate heat loss [19]. Ambient temperature in a pig house proves to be a key element affecting animal welfare and thus influencing production performance. It was reported that sows held periodically at 25 °C or 28 °C were characterized by longer farrowing, more aggressive behaviour, a higher number of stillborn piglets, and lower body mass in subsequent periods [3]. It ultimately affected litter size and litter weight at birth, chemical composition and SCC of colostrum and milk. Solids content was lowest in the colostrum and milk from sows at 28 °C and highest in sows at 22 °C. A similar tendency was found for protein and fat content of milk. Increased levels of SCC may be associated with high ambient temperature.

An environmental temperature range of 18 to 21 °C generally has been found to support optimal productive performance of growing-finishing pigs. Pigs have a limited capacity to lose heat by water evaporation (EW) from the skin [20]. At higher ambient temperature the pig show increased respiration rate, rectal temperature and decreased voluntary feed intake [32, 39]. In addition to experiencing increased heat loss, the pigs increase the exposure of their bodies to cool air or cool and wet floors [2]. Ambient temperature strongly affects the physiological changes and performance of pig, whereas relative humidity has a relatively lesser effect on heat stress in growing pigs; however, the combination of high temperature and relative humidity lowered the average daily gain in pigs. Above the upper critical temperature, feed intake decreased and rectal temperature increased [18].

Increasing ambient temperature from 22 to 29 °C resulted in a 15 % reduction in average daily feed intake and 13 % lower in average daily gain in crossbred pigs (Piétrain × Landrace × Large White) [24]. It was observed that in the temperature range of 21 to 32 °C, the growth rate of 70 kg pigs was decreased by 46 %. The decrease in average daily gain of the pigs seemed to be caused mainly by the drop of voluntary feed intake during heat stress [17, 47]. It was reported that in the cool season (ambient temperature 24.6 °C and relative humidity 84 %), neither voluntary feed intake, nor average daily gain, feed: gain ratio or carcass characteristics significantly differed from control environment (ambient temperature 20 °C and relative humidity 75 %). In the warm season (ambient temperature 27.3 °C and relative humidity 82 %), the 13 % decline in feed intake of pigs induced a 13 % diminution in growth rate ($P<0.05$). In the warm season, fat percentage of the carcass was reduced by 3.2 units, whereas less fat was deposited in back fat and more fat retained in leaf fat, as compared to the cool season. It was also observed that water intake and drinking frequency of pig were increased for enhancing heat dissipation and maintaining milk yield [43]. Pig production losses occur when animals are exposed to elevated temperature for a significant duration and intensity [25]. Owing to inefficient thermoregulation, pigs are reported to be more sensitive to hot environmental conditions [31]. It was reported that growth, carcass lipid quality, and bacon quality decreased in pigs, housed at temperatures above the thermoneutral zone, *i.e.*, 32 °C; however, increasing the floor space allocation for housing may be a means to ameliorate the negative effects of heat stress [54].

It was reported that heat stress conditions reduce the FCR. The optimum temperature range is considered to be 10 °C to 23.9 °C for pigs weighing between 54.5 and 118.2 kg. High temperature had negative effect on average daily feed intake and average daily gain and this effect was more pronounced in heavier pigs. Pig performance decreased at an accelerating rate as temperature increased [29, 41].

Weekly air temperature had negative influence on weekly live weight which was reduced by 4.26, 3.89 and 5.26 kg in a week per degree centigrade rise of air temperature in a week in Large White Yorkshire (LWY), Goa Local (GL) and Cross bred (CB) pigs respectively. So, influence of change of average air temperature was most pronounced on CB pigs followed by LWY and GL pigs. In LWY pig average daily gain was decreased significantly by 132 g per unit increase of average air temperature. In GL and CB pig reduction of average daily gain were 106 and 148 g respectively. Here maximum impact of air temperature was observed on CB pigs than LWY and GL pigs [10].

It was indicated [21, 22, 42] that heat stress negatively affects live weight gains in pigs and suggested that this may be related to the course of physiological processes in the body caused by an increase in body temperature.

The heat stress has a more pronounced effect on reproductive performance in gilts than in mature sows [4].

It was established [23] that increasing air mobility at high ambient temperature has a positive effect on the health of pigs, increasing heat output and preventing overheating. With an uneven distribution of air flows in the shed, there are dead zones, that is, zones with a reduced air movement speed (less than 0.05 m/s) and a high concentration of harmful gases, dust and microorganisms, which has a negative effect on the health of animals.

It was reported [35] that an increase in body temperature caused morphological changes in the intestines of pigs, since animals under heat stress have a higher body temperature and may have more intestinal damage than in animals that are in comfortable conditions. In addition, under the influence of high temperatures, the secretion of gastric juice was suppressed, its bactericidal function was insufficient, the activity of pepsin decreased and the concentration of total protein in the blood increased. The proteolytic group of enzymes — pepsin, trypsin, enterokinase — were most inhibited, as a result of which digestion processes was worsen and the rate of absorption of amino acids decreased. In addition, pancreatic enzyme secretion was inhibited, intestinal motility was suppressed.

In a study it was observed that the lowest weight gain (58.70 kg), feed intake (152.93 kg), carcass weight (79.70 kg) and back-fat thickness (15.90 mm) was observed in cross bred pigs (Duroc × Landrace × Yorkshire) maintained at 31 °C to 37 °C ($P<0.05$). They also reported that the temperature range of pig house from 12 °C to 19 °C imparts maximum weight gain (77.25 kg), feed intake (197.32 kg), carcass weight (92.20 kg) and back fat thickness (22.30 mm) respectively. It was reported that temperatures around 34 °C would reduce the average daily gain and average daily feed intake of growing-finishing pigs [34]. So, they concluded that the temperature range from 12 °C to 19 °C imparts optimum growth performances, carcass traits parameters. They also reported that environmental temperature influences the growth performances, carcass characteristic and meat quality of pigs. High ambient temperature adversely affects growth performances and carcass characteristics. Consequently, there is diminishment in the ultimate meat quality parameters. Considering the results obtained, they concluded that the temperature range from 12 °C to 19 °C imparts optimum growth performances and carcass traits of crossbred pigs (Duroc × Landrace × Yorkshire). The reduction of feed intake is a mechanism to minimize the amount of heat production from various metabolic and digestive activities [28]. The temperature fluctuations and elevated temperature in summer impairs the thermoregulation process of the animal, thereby resulting in stress and inferior meat quality [15, 46]. The reduced back-fat thickness was recorded in pigs reared in tropical climate than in a controlled environment (20 °C) [44]. It was reported that pigs slaughtered during winter had the highest slaughter weight and back-fat thickness, whereas in summer season lower slaughter weight, lower hot carcass weight and depleted cold carcass weight were observed. This could be due to increased voluntary feed intake in winter which caused higher live weight and higher back-fat thickness. Pigs exhibit both behavioral and physiological adaptations in response to heat stress to maintain their body temperature within the normal range [8]. Seeking shelter is one of the primary behavioral responses observed in heat-stressed pigs. However, indigenous animals adapted to tropical regions are generally more heat tolerant and may spend more time in grazing rather than resting in shaded areas. A reduction in feed intake is another important behavioral response to heat stress, as it helps minimize metabolic heat production under high ambient temperatures. This reduction in feed intake represents an adaptive mechanism because the digestion and metabolism of nutrients contribute substantially to endogenous heat production. Heat-stressed pigs also exhibit increased water intake and drinking frequency to facilitate evaporative and non-evaporative heat dissipation. In addition, alterations in urination and defecation frequency, standing and lying time, and shelter-seeking behavior have been reported as major behavioral responses associated with heat stress in pigs [50].

It was reported [5] that the THI was above the thermal comfort zone in seven months of the year in an organized farm of Assam. So availability of crude protein (CP) and metabolizable energy (ME) was lesser in grower gilts. It was also found that with the increase of THI, concentration of Insulin like growth factor binding protein receptor (IGFBPR) and Insulin like growth factor binding protein (IGFBP) were increased.

In livestock sector GHG emission from piggery stands second. Overall GHG emissions from pig houses were estimated to 448.4 kg CO_2 equivalent per slaughter pig produced. It was also reported that the fattening period of pig contributed more than 70 % of total GHG emissions, while the gestation, lactation and weaning periods each was accounted for 10 % of total GHG emissions [37].

Methane is a dangerous greenhouse gas and it is found that global warming potential of methane is 21 times greater than that of carbon dioxide, and it is responsible for 18 % of the global GHG effect [27]. CH_4 released from pig slurry is produced by the anaerobic decomposition of organic matter by bacteria. This process takes place mainly (65–75 %) during storage of pig slurry, but may also occur after its application in fields. CH_4 present in pig shed is also generated as a result of bacterial fermentation in the large intestine of pigs [26]. It was reported that estimated daily enteric CH_4 emissions was 0.8 and 0.9 g per head for weaned piglets up to 20 kg body weight, 2.4 and 2.5 g for fattening pigs above 20 kg body weight, 8.2 and 6.1 g per head for reproductive sows under French and German production conditions respectively. The second important source of methane (10–15 %) is the anaerobic breakdown of animal faeces [9, 51]. It was also reported that high temperature, high level of degradable organic matter, high moisture content, neutral pH, and a C: N ratio of between 15 and 30 favoured methane production [7].

Carbon dioxide is a key greenhouse gas; its global warming potential (GHG) by definition is 1 [26]. The livestock sector accounts for the formation of about 9 % of global emissions of carbon dioxide [52]. CO_2 emitted from pig slurry is generated during putrefaction and fermentation processes (aerobic and anaerobic decomposition of organic substances) taking place in pig slurry, as well as during hydrolysis of urea. Another source of CO_2 in piggeries is the animals' respiration. It was observed that fattening pigs excrete about 1.70 kg of carbon dioxide per day with exhaled air. Smaller amounts of CO_2 are released from manure during hydrolysis of urea, aerobic and anaerobic degradation of organic matter [36].

Ammonia (NH_3) emissions were highly correlated with animal activity and especially with feeding and excretory behavior of pig. NH_3 concentrations in swine buildings showed large variations and depend on number of factors such as age of pig, activity and stocking density of pig in the pig house, outdoor temperature, ventilation system of pig shed etc. [45]. Season had significant impact on ammonia emissions rate which was higher in summer season (7.0 g NH_3/pig/day) than that in winter season (3.0 g NH_3/pig/day). The higher ammonia emission rate in summer was due to higher ambient temperature and lower ventilation rate in pig house during summer season. It was also indicated that ammonia emissions were highly correlated with feeding and excretory behavior of pig [36].

Adaptation Strategies

Adaptation to climate change refers to an adjustment or preparation of livestock to new or changing environmental condition and the adoption of practices that help to reduce the adverse effects of climate change on animal performance. Such adaptations can minimize the risks associated with climate change and help to address emerging environmental challenges. Air temperature and relative humidity are among the most important environmental factors affecting pig health, welfare, and productivity, and prolonged exposure to unfavorable conditions can have deleterious effects on production.

Animal housing is an important component of livestock husbandry, particularly from the perspectives of animal welfare, health, and productivity. Various cooling devices and management interventions are available to alleviate heat stress, each having its own advantages and limitations. Although well-designed housing provides considerable control over environmental stressors, it often requires substantial initial investment per animal. Therefore, the development and adoption of low-cost housing systems are particularly important for climate-resilient pig production. Such housing systems should provide an optimal microenvironment by reducing heat load and protecting pigs from adverse climatic conditions while keeping construction and maintenance costs as low as possible.

Extensive studies have been conducted in several countries to evaluate the effects of shed construction materials and shed orientation on the microclimate in pig houses. The orientation of a pig shed is an important factor that should be given due consideration during shed construction, particularly under different climatic conditions. An east–west orientation of the pig shed is preferable in extremely hot and low-rainfall regions (10–12 cm annual rainfall), as it helps to minimize direct solar radiation and keeps the ground beneath the shed relatively cooler. In contrast, a north–south orientation exposes the area beneath the shed to morning and afternoon sunlight, which facilitates drying and helps to maintain a relatively dry environment. Therefore, this orientation may be more suitable for sub-temperate to temperate climates, particularly in hilly and high-rainfall regions. Roofing materials should preferably have low thermal conductivity to reduce the transfer of heat into the shed and minimize heat stress in pigs. Installation of a false ceiling can further reduce heat entry through the roof. In addition, painting the roof with reflective white paint can significantly reduce the absorption of solar radiation and thereby help to mitigate heat stress in pigs.

The feeding behavior of most animals' changes during the summer season, with animals tending to consume more feed during the cooler periods of the day [53]. Therefore, providing feed during cooler periods can help maintain normal feed intake, reduce metabolic disturbances, and minimize heat load. In addition, reducing the crude protein content of the diet while supplementing essential amino acids such as methionine, lysine, threonine, and tryptophan can significantly reduce nitrogen excretion without compromising animal performance. Reducing the level of crude protein in the diet of pigs by up to 12 % can decrease the release of odorous compounds from manure by 40 % [6]. The inclusion of organic acids, including benzoic acid, or fibre as feed additives reduces NH_3 emissions by more than 60 % [12, 13].

In a study with piglets, it was reported that daily weight gain increased considerably by 12.2 % while exposed to ionized air compared to control animals. Ionization also had a positive influence on the weaning weight of the piglets, which increased by 9.3 %. Piglet health is also improved, translating into 2.61 % lower mortality. So, negative air ionization improves microclimate conditions in livestock buildings, which translates directly into improved health and productivity of farm animals. So, negative air ionization as a physical microclimate factor largely depends on thermal and humidity conditions in buildings. It has a considerable effect on the organism, which translates into the health, well-being and productivity of animals [16].

The positive effects of other biologically active substances, including probiotics, prebiotics and herbal preparations, are well known. It was demonstrated that a probiotic animal feed supplement containing the bacteria *Lactobacillus acidophilus*, *Bacillus subtilis* and *Clostridium butyricum* increases the absorption of amino acids and decreases the content of nitrogen compounds in the manure, thereby reducing ammonia emission [55]. It was observed that the use of 0.2 % symbiotics containing bacteria and yeast significantly reduces the amount of ammonia and hydrogen sulphide in the faeces [40].

Mitigation Strategies

Several mitigation strategies can be adopted to reduce methane emissions from livestock. In India, however, the potential for reducing methane emissions from manure storage is relatively limited because livestock dung is widely utilized as a fuel source in the form of dried dung cakes. Therefore, in pig production, greater emphasis should be placed on improving digestive and metabolic efficiency through nutritional interventions.

Several nutritional technologies can improve digestive and metabolic efficiency in pigs, including dietary manipulation, methane inhibitors, feed additives, propionate enhancers, methane oxidizers, probiotics, and hormonal interventions. Studies conducted in India using some of these approaches have reported encouraging results, with potential reductions in methane emissions ranging from 5 to 25 %.

Improving feed conversion efficiency is another effective approach to reducing methane emissions. Feeding pigs with concentrate-rich diets can enhance growth rate and enable them to attain slaughter weight in a shorter period, thereby reducing the duration of methane production. In one study, increasing the proportion of concentrate in the diet reduced methane production by 15–32 %. This reduction was attributed to the improved quality of the diet, which decreased the proportion of feed nutrients converted into methane [14].

Lactic acid-producing bacteria, especially those belonging to the *Lactobacillus* genus, are present in many Direct-fed microbials (DFMs). Lactate and short-chain fatty acids like acetate and propionate are produced when these organisms ferment water-soluble carbohydrates, mostly through the phosphoketolase and acrylate pathways. In addition to diverting metabolic hydrogen away from methane formation and toward the production of alternative end products like propionate, this fermentation pattern lowers ruminal pH to levels that are less than ideal for methanogenic archaea. This hydrogen redirection helps the host to produce energy-producing volatile fatty acids while reducing net methane emissions [30].

Culling unproductive and stunted pigs, as well as excessively fattened pigs, wherever feasible, may help to reduce methane emissions by improving overall production efficiency. Enteric methane emission per kilogram of dry matter intake has been reported to increase under severe heat stress. Therefore, protecting pigs from heat stress through appropriate housing, ventilation, and cooling management can help in reducing methane emissions.

Improved management and disposal of farmyard manure can also contribute to methane mitigation. Anaerobic digestion of manure for biogas production can reduce methane emissions, while the resulting biogas slurry can be effectively utilized as a fertilizer in agricultural fields or as an organic nutrient source in fish ponds. Thus, adopting improved manure-management practices, particularly biogas production, can contribute in reducing the methane emissions from pig farms [48].

Previously considered an environmental liability, manure management technologies have become an essential part of sustainable livestock systems, transforming manure into a source of renewable energy, nutrient recovery, and soil regeneration. Effective manure management is crucial for reducing greenhouse gas emissions, improving resource efficiency, and promoting circular bio economy models as the volume and intensity of livestock production rise worldwide [49].

Scientific housing with proper orientation, adequate ventilation, sufficient floor space, roof painting, and the use of false ceilings can significantly improve the comfort and welfare of pigs under hot climatic conditions. Appropriate cooling measures, such as ceiling fans, water spraying or sprinkling, and splashing of water followed by air circulation using fans, are effective in alleviating heat stress. Routine farm activities should preferably be scheduled during the cooler parts of the day, particularly in the early morning and late afternoon, while night-time grazing may also be practiced where feasible. Provision of a low-fiber, energy-dense diet along with adequate quantities of clean, cool drinking water is essential to minimize the adverse effects of heat stress on feed intake, growth, production, and reproductive performances of pig. Other mitigation measures include the use of antioxidants and suitable feed additives, ensiling of fodder, scientific manure management, timely removal of unproductive animals, and promotion of indigenous or climate-resilient pig breeds. Furthermore, stronger linkages among scientists, farmers, state government departments, extension personnel, and non-governmental organizations (NGOs) are essential for creating awareness about the impacts of climate change and ensuring the effective implementation of adaptation and mitigation strategies suited to specific agro-climatic conditions and regions.

References

1. Anonymous. 20th Livestock Census. Department of Animal Husbandry & Dairying; Ministry of Fisheries, Animal Husbandry & Dairying. Govt. of India. New Delhi, 2019.
2. Aarnink AJA, Schrama JW, R. Verheijen JE, Stefanowska J. Pen fouling in pig houses affected by temperature. *Livest Environ VI: Proc. 6th Int. Symposium*, Louisville, Kentucky, USA, 21–23 May, 2001: 180–186. DOI: 10.13031/2013.7071.
3. Babicz M, Skrzypczak E, Rejduch B, Kozubska-Sobocińska A, Chmielowiec-Korzeniowska A, Kasprzak K. Effect of thermal stress on reproductive performance parameters of sows with defined genotype at the *RYR1* locus. *Ann Anim Sci*. 2012; 12 (3): 323–333. DOI: 10.2478/v10220-012-0027-1.
4. Bloemhof S, Mathur PK, Knol E, van der Waaij EH. Effect of daily environmental temperature on farrowing rate and total born in dam line sows. *J Anim Sci*. 2013; 91 (6): 2667–2679. DOI: 10.2527/jas.2012-5902.
5. Borah S, Soren S, Talukdar R, Kalita L, Pame K, Nath AJ, Borah B, Pathak PK, Bhattacharya BN. Thermal Stress impaired expression of insulin like growth factor binding properties in pigs. *Ind J Anim Sci*. 2023; 93 (3): 303–308. DOI: 10.56093/ijans.v93i3.128685.
6. Cho S, Hwang O, Park S. Effect of dietary protein levels on composition of odorous compounds and bacterial ecology in pig manure. *As Australas J Anim Sci*. 2015; 28 (9): 1362–1370. DOI: 10.5713/ajas.15.0078.
7. Chmielowiec-Korzeniowska A, Tymczyna L, Wlazło Ł, Trawińska B, Ossowski M. Emissions of gaseous pollutants from pig farms and methods for their reduction — A review. *Ann Anim Sci*. 2022; 22 (1): 89–107. DOI: 10.2478/aoas-2021-0015.
8. Čobanović N, Bošković M, Vasilev D, Dimitrijević M, Parunović N, Djordjević, J, Karabasil N. Effects of various pre-slaughter conditions on pig carcasses and meat quality in a low-input slaughter facility. *South Afr J Anim Sci*. 2016; 46 (4): 380–390. DOI: 10.4314/sajas.v46i4.6.
9. Dämmgen U, Schulz J, Klausing HK, Hutchings NJ, Haenel HD, Rösemann C. Enteric methane emissions from German pigs. *Landbauforschung Volkenrode.* 2012; 62: 83–96. Available at: https://www.thuenen.de/media/publikationen/landbauforschung/Landbauforschung_Vol62_3.pdf#page=23
10. Das SK, Singh NP. Effect of microclimatological changes on pig production. *Environ Ecol.,* 2016; 34 (1): 56–59.
11. Elischer M. Animal Welfare at the Fair: Thermoregulation and thermoneutral zone. Michigan State University Extension, 2021.
12. Eriksen J, Nørgaard JV, Poulsen HV, Jensen BB, Petersen SO. Effects of acidifying pig diets on emissions of ammonia, methane, and sulfur from slurry during storage. *J Environ Qual*. 2014; 43 (6): 2086–2095. DOI: 10.2134/jeq2014.03.0108.
13. Galassi GS, Colombini L, Malagutti G, Crovetto A, Rapetti L. Effects of high fibre and low protein diets on performance, digestibility, nitrogen excretion and ammonia emission in the heavy pig. *Anim Feed Sci Technol*. 2010; 161 (3–4): 140–148. DOI: 10.1016/j.anifeedsci.2010.08.009.
14. Garnett T. Meat and dairy production and consumption: Exploring the livestock Sector's contribution to the UK's greenhouse gas emissions and assessing what less greenhouse gas intensive systems of production and consumption might look like food. *Climate Res Network*. 2007.
15. Guàrdia MD, Estany J, Balasch S, Oliver MA, Gispert M, Diestre A. Risk assessment of DFD meat due to pre-slaughter conditions in pigs. *Meat Sci*. 2005; 70 (4): 709–716. DOI: 10.1016/j.meatsci.2005.03.007.
16. Hagen D. Ionic system aids air quality for nursery pigs. *Feedstuffs*. 2012; 26: 16–21.
17. Huynh TTT. *Heat Stress in Growing Pigs*. Wageningen Institute of Animal Science, 2005:45–66.
18. Huynh TTT, Aarnink AJA, Gerrits WJJ, Heetkamp MJH, Canh TT, Spoolder HAM, Kemp B, Verstegen MWA. Thermal behaviour of growing pigs in response to high ambient temperature and humidity. *Appl Anim Behav Sci*. 2005; 91 (1–2): 1–16. DOI: 10.1016/j.applanim.2004.10.020.
19. Huynh TTT, Aarnink AJA, Verstegen MWA, Gerrits WJJ, Heetkamp MJW, Kemp B, Canh TT. Effects of increasing temperatures on physiological changes in pigs at different relative humilities. *J Anim Sci*. 2005; 83 (6): 1385–1396. DOI: 10.2527/2005.8361385x.
20. Ingram DL. Evaporative cooling in the pig. *Nature*. 1965; 207: 415–416. DOI: 10.1038/207415a0.
21. Johnson J, Abuajamieh M, Sanz Fernandez MV, Seibert JT, Stoakes SK, Nteeba J, Keating AF, Ross JW, Rhoads RP, Baumgard L. Thermal stress alters postabsorptive metabolism during pre- and postnatal development. In: Sejian V, Gaughan J, Baumgard L, Prasad C (eds). *Climate Change Impact on Livestock: Adaptation and Mitigation*. New Delhi, (India), Springer India Publishing House, 2015: 61–79. DOI: 10.1007/978-81-322-2265-1_5.
22. Kerr BJ, Yen JT, Nienaber JA, Easter RA. Influences of dietary protein level, amino acid supplementation and environ-mental temperature on performance, body composition, organ weights and total heat production of growing pigs. *J Anim Sci*. 2003; 81 (8): 1998–2007. DOI: 10.2527/2003.8181998x.
23. Krommweh M, Rösmann P, Büscher W. Investigation of heating and cooling potential of a modular housing system for fattening pigs with integrated geothermal heat exchanger. *Biosys Eng*. 2014; 121: 118–129. DOI: 10.1016/j.biosystemseng.2014.02.008.
24. Le Bellego L, Van Milgen J, Noblet J. Effect of high temperature and low-protein diets on the performance of growing-finishing pigs. *J Anim Sci*. 2002; 80 (3): 691–701. DOI: 10.2527/2002.803691x.
25. Lucas EM, Randall JM., Meneses JF. Potential for evaporative cooling during heat stress periods in pig production in Portugal (Alentejo). *J Agric Eng Res*. 2000; 76 (4): 363–371. DOI: 10.1006/jaer.2000.0550.
26. Marszałek M, Kowalski Z, Makara A. Emission of greenhouse gases and odorants from pig slurry — effect on the environment and methods of its reduction. *Ecol Chem Eng S*. 2018; 25 (3): 383–394. DOI: 10.1515/eces-2018-0026.
27. Mohajan HK. Dangerous effects of methane gas in atmosphere. *Int J Econ Politic Integr*. 2012; 1 (2): 3–10. Available at: https://mpra.ub.uni-muenchen.de/50844
28. Mun HS, Rathnayake D, Dilawar MA, Jeong MG, Yang CJ. Effect of ambient temperature on growth performances, carcass traits and meat quality of Pigs. *J Appl Anim Res*. 2022; 50 (1): 103–108. DOI: 10.1080/09712119.2022.2032084.
29. Myer RO, Bucklin RA. Effect of season (summer *vs.* fall) and diet nutrient density on performance and carcass characteristics of growing finishing swine. *Transact ASAE.* 2002; 45 (3): 807–811. DOI: 10.13031/2013.8853.
30. Narasimha S, Zackria R, Chadha R, Gheriani A, Johnson L, Pattison R, Kim A, Chen GQ, Ryan J, Shih DQ. The various healthcare applications of the genus *Lactobacillus*. In: Laranjo M (ed). *Exploring Lactobacilli — Biology, Roles and Potential Applications in Food Industry and Human Health*. IntechOpen, 2025. DOI: 10.5772/intechopen.115299.

31. Nardone A, Ronchi B, Lacetera N, Ranieri MS, Bernabucci U. Effects of climate changes on animal production and sustainability of livestock systems. *Livest Sci*. 2010; 130 (1–3): 57–69. DOI: 10.1016/j.livsci.2010.02.011.
32. Nienaber JA, Hahn GL, McDonald TP, Korthals RL. Feeding patterns and swine performance in hot environments. *Transact ASAE*. 1996; 39 (1): 195–202. DOI: 10.13031/2013.27498.
33. Nienaber JA, Hahn GL. Associations among body temperature, eating and heat production in swine and cattle. *Energy Metabolism of Farm Animals*, EAAP Publ. no. 58, Zurich, Switzerland, 1998: 458–461.
34. Oliveira RF, Moreira RHR, Abreu MLT, Gionbelli MP, Teixeira AO, Cantarelli VS, Ferreira RA. Effects of air temperature on physiology and productive performance of pigs during growing and finishing phases. *South Afr J Anim Sci*. 2018; 48 (4): 627–635. DOI: 10.4314/sajas.v48i4.4.
35. Pearce SC, Mani V, Boddicker RL, Johnson JS, Weber TE, Ross JW, Baumgard LH, Gabler NK. Heat stress reduces barrier function and alters intestinal metabolism in growing pigs. *J Anim Sci*. 2012; 90 (4): 257–259. DOI: 10.2527/jas.52339.
36. Philippe FX, Cabaraux JF, Nicks B. Ammonia emissions from pig houses: Influencing factors and mitigation techniques. *Agric Ecosys Environ*. 2011; 141 (3–4): 245–260. DOI: 10.1016/j.agee.2011.03.012.
37. Philippe FX, Nicks B. Review on greenhouse gas emissions from pig houses: Production of carbon dioxide, methane and nitrous oxide by animals and manure. *Agric Ecosys Environ.* 2015; 199: 10–25. DOI: 10.1016/j.agee.2014.08.015.
38. Prunier A, Messiasde de Bragança M, Le Dividich J. Influence of high ambient temperature on performance of reproductive sows. *Livest Prod Sci*. 1997; 52 (2): 123–133. DOI: 10.1016/S0301-6226(97)00137-1.
39. Quiniou N, Noblet J, Van Milgen J, Dubois S. Modelling heat production and energy balance in group-housed growing pigs exposed to low or high ambient temperatures. *Br J Nutr*. 2001; 85 (1): 97–106. DOI: 10.1079/BJN2000217.
40. Recharla N, Kim K, Park J, Jeong J, Jeong Y, Lee H, Hwang O, Ryu J, Baek Y, Oh Y, Park S. Effects of amino acid composition in pig diet on odorous compounds and microbial characteristics of swine excreta. *J Anim Sci Technol*. 2017; 59: 28–36. DOI: 10.1186/s40781-017-0153-5.
41. Renaudeau D, Gourdine JL, St-Pierre NR. A meta-analysis of the effect of high ambient temperature on growth performance of growing–finishing pigs. *J Anim Sci*. 2011; 89 (7): 2220–2230. DOI: 10.2527/jas.2010-3329.
42. Renaudeau D, Collin A, Yahav S, de Basilio V, Gourdine JL, Collier RJ. Adaptation to hot climate and strategies to alleviate heat stress in livestock production. *Animal*. 2012; 6 (5): 707–728. DOI: 10.1017/S1751731111002448.
43. Rinaldo D, Le Dividich J, Noblet J. Adverse effects of tropical climate on voluntary feed intake and performance of growing pigs. *Livest Prod Sci*. 2000; 66 (3): 223–234. DOI: 10.1016/S0301-6226(00)00181-0.
44. Rinaldo D, Mourot J. Effects of tropical climate and season on growth, chemical composition of muscle and adipose tissue and meat quality in pigs. *Anim Res*. 2001; 50 (6): 507–521. DOI: 10.1051/animres:2001142.
45. Rodriguez MR, Losada E, Besteiro R, Arango T, Velo R, Ortega JA, Fernandez MD. Evolution of NH_3 concentrations in weaner pig buildings based on set point temperature. *Agronomy*. 2020; 10 (1): 107. DOI: 10.3390/agronomy10010107.
46. Santos C, Almeida JM, Matias C, Fraqueza MJ, Roseiro C, Sardina L. Influence of lairage environmental conditions and resting time on meat quality in pigs. *Meat Sci*. 1997; 45 (2): 253–262. DOI: 10.1016/S0309-1740(96)00048-4.
47. Serres H. *Manual of Pig Production in the Tropics*. 2nd ed. CAB Int., Cedex, France, 1992. DOI: 10.1079/9780851987842.0000.
48. Suriyasathaporn W, Boonyayatra S, Kreausukon K, Pinyopummintr T, Heuer C. Modification of Microclimate to Improve Milk Production in Tropical Rainforest of Thailand. *As Australas J Anim. Sci*. 2006; 19 (6): 811–815. DOI: 10.5713/ajas.2006.811.
49. Symeon G, Akamati K, Dotas V, Karatosidi D, Bizelis I, Laliotis GP. Manure management as a potential mitigation tool to eliminate greenhouse gas emissions in livestock systems. *Sustainability*. 2025; 17 (2): 586. DOI: 10.3390/su17020586.
50. Temple D, Manteca X. Animal welfare in extensive production systems is still an area of concern. *Front Sust Food Sys*. 2020; 4: 545902. DOI: 10.3389/fsufs.2020.545902.
51. Vermorel M, Jouany JP, Eugène M, Sauvant D, Noblet J, Dourmad JY. Evaluation quantitative des émissions de méthane entérique par les animaux d'élevage en France. *INRA Prod Anim*. 2008; 21 (5): 403–418. (in French)
52. Vorobel M, Kaplinskyi V, Klym O, Prudyus T, Lopotych N, Momut V, Bilovus H, Stefanyshyn O, Tsap M, Pylypets A, Smolyaninova O, Luchka I. Animal waste as a source of GHG emissions and a factor of climate change. *Sci Pap Ser D Anim Sci*. 2023; LXVI (2): 428–435. DOI: 10.17930/ANS2023250.
53. West JW. Nutritional strategies for managing the heat stressed dairy cow. *J Anim Sci*. 1999; 77 (2): 21–35. DOI: 10.2527/1997.77suppl_221x.
54. White HM, Richert BT, Schinckel AP, Burgess JR, Donkin SS, Latur MA. Effects of temperature stress on growth performance and bacon quality in grow-finish pigs housed at two densities. *J Anim Sci*. 2008; 86 (8): 1789–1798. DOI: 10.2527/jas.2007-0801.
55. Zhang ZF, Kim IH. Effects of multistrain probiotics on growth performance, apparent ileal nutrient digestibility, blood characteristics, cecal microbial shedding, and excreta odor contents in broilers. *Poult Sci*. 2014; 93 (2): 364–370. DOI: 10.3382/ps.2013-03314.

Вплив зміни клімату на свинарство — стратегії адаптації та пом'якшення негативного впливу

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У статті розглянуто вплив зміни клімату на ріст, споживання корму, вихід туші, а також внесок свиней у продукцію парникових газів. Повідомлялося, що підвищення температури довкілля з 22 до 29 °C призвело до зниження середньодобового споживання корму на 15 % та середньодобового приросту на 13 % у кросбредних свиней. Було виявлено, що діапазон температури від 18 до 21 °C сприяє оптимальній продуктивності свиней на етапі вирощування та відгодівлі, з огляду на обмежену тепловіддачу в них через шкірне випаровування вологи, тобто потовиділення. Стабільний тепловий стрес негативно впливає на травну функцію та репродуктивні показники свиней. У свинарниках наявні метан, вуглекислий газ та аміак, які виділяються зі свинячого гною. Також обговорено різні заходи адаптації та пом'якшення наслідків. Наукове утримання з правильним розташуванням, вентиляцією, забезпеченням достатньої площі, покриттям даху білою фарбою, використанням підвісної стелі сприяли комфорту свиней. Впровадження охолоджувальних систем у приміщенні зменшить тепловий стрес. Рекомендовано планувати більшість заходів вдосвіта та під вечір, практикувати нічний випас. Для подолання негативного впливу теплового стресу на годівлю, продуктивність та репродуктивні показники дуже важливо забезпечити свиней високоенергетичним раціоном з низьким вмістом клітковини та холодною чистою питною водою. Використання антиоксидантів, кормових добавок, силосування кормів, науковий підхід до поводження з гноєм, зменшення поголів'я непродуктивних свиней та використання місцевих порід — це деякі із заходів для пом'якшення негативних наслідків.

Ключові слова: свині, зміна клімату, тепловий стрес, адаптація, пом'якшення наслідків

Das SK. Impact of climate change on pig production — adaptation and mitigation strategies. *Biol Tvarin*. 2026; 28 (2): 3–9. DOI: 10.15407/animbiol28.02.003.