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Research Paper

# An innovative concept building design incorporating passive technology to improve resource efficiency and welfare of finishing pigs

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In conventionally-designed buildings for finishing pigs, extreme weather conditions can impact negatively on feed utilisation and animal welfare. The SPaTHE (Solar, Passive, Thermal, Heat Exchange) concept is an innovative, resource-efficient engineered building designed to provide an internal environment where finishing pigs can thrive. Passive design elements include solar shading and capture combined with integrated earth tubes to facilitate heat exchange with incoming fresh air to reduce extreme summer and winter internal temperatures. The SPaTHE specification was dynamically modelled and compared to an existing conventional finisher building operating in the UK. The same dimensions (18 m × 14 m) and build specification were used for each building, which was designed to hold 292 pigs from 20 to 100 kg liveweight. Results showed that pigs in the optimum configuration of conventional building form spent 661 fewer h $y^{-1}$ in conditions <19 °C, and 102 fewer h $y^{-1}$ in conditions >28 °C than with a standard building. Whereas with the SPaTHE design, during 2222 h $y^{-1}$ the pigs were kept at optimum conditions between 19 °C to 22 °C. The model also estimated that the SPaTHE design would reduce the peak summer internal operative temperature by 3.4 °C when the external temperature was 28 °C, and increase the peak winter internal operative temperature by 1.2 °C when the external air temperature is −5.4 °C. Hence the concept design potentially provides an environment which more closely matches the needs of finishing pigs and thus may contribute to more sustainable food production systems.



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**Nomenclature**

| | |
|---|---|
| ac $h^{-1}$ | Infiltration of air |
| DT | Dynamic Thermal model |
| kg | Liveweight of pigs |
| kJ $m^{-2}$ $K^{-1}$ | Thermal Mass |
| kW h $y^{-1}$ | Annual electrical energy consumption |
| LHP | Latent Heat Produced by the pig |
| l $s^{-1}$ | Volume flow rate |
| lx | Illuminance levels |
| $m^3$ $h^{-1}$ | Volume flow rate |
| m $s^{-1}$ | Air velocity |
| NOAA | National Oceanic and Atmospheric Administration |
| $q_e$ | Sensible heat gain of sensible heat to latent heat |
| $q_f$ | Sensible heat gain through the floor |
| $q_h$ | Sensible heat gain from heating systems |
| $q_m$ | Sensible heat gains from 'mechanical' sources |
| $q_s$ | Sensible heat gains from animals |
| $q_{so}$ | Sensible heat gain from solar radiation |
| $q_{vi}$ | Sensible heat gain from supply ventilation air |
| $q_{vo}$ | Sensible heat gain contained in the extract ventilation air |
| $q_w$ | Sensible heat gain through the building fabric (excl. floor) |
| SPaTHE | Solar, Passive, Thermal and Heat exchange concept building design |
| SHP | Sensible Heat Produced by the pig |
| THP | Total Heat Produced by the pig |
| TRY | Test Reference Year weather files |
| W $m^{-2}$ $K^{-1}$ | U-Value |

## 1. Introduction

Compared to many other livestock reared for meat production, pigs have a relatively low level of insulation in their coats which makes them more sensitive to changes in the housed internal environment. When pigs are exposed to colder conditions, their level of thermoregulatory heat production increases, energy retention from consumed nutrients is depressed and, as a result, feed efficiency is reduced (Lopez, Jesse, Becker, & Ellersieck, 1991). For housed pigs, the environmental temperature range that means they neither need to divert nutrients to keep warm nor reduce feed intake to keep cool is known as the thermoneutral zone (Mount, 1975). When housed in these conditions throughout the finishing production programme, pigs will return a higher feed efficiency and show improved well-being. However, when housed in typical current UK buildings during a typical UK year, maintaining this thermoneutral zone can be challenging (Jackson, Guy, Edwards, Sturm, & Bull, 2017). This is particularly so if the temperature control in the finishing room relies solely on varying the incoming fresh air via fan ventilation, rather than heating and cooling the air supply, or cooling via a high-pressure misting system. In UK pig finishing buildings, heating and cooling systems for the incoming air are usually not used, due to their associated increased installation, energy and maintenance costs. Cold weather can therefore have a detrimental effect not only on pig productivity, because nutrients are diverted from growth to heat production, but also on the internal air quality, this is because the predominant ventilation control factor is the minimum temperature set point until a fixed minimum ventilation rate is reached (Jackson et al., 2017). Potential faults to ventilation fans, and the possibility for farm staff to alter this minimum fresh air rate if, for example they feel the internal temperature is too cool during extreme cold spells, can exacerbate this problem. The need to maintain a higher minimum ventilation rate can result in farms installing supplementary heating for smaller pigs during cooler external conditions.

Similarly, very warm weather can also have a detrimental effect on pigs. When the internal environmental temperature increases, pigs will attempt to lie separate from each other and try to place as much body surface area as possible onto a cool or wet surface to help dissipate heat, which can result in wallowing in manure. If the temperature increases further, they will begin to reduce their feed intake in order to decrease their metabolic heat production. This heat stress-induced reduction in feed intake has a significant impact on pig productivity (Renaudeau, Gourdine, & St-Pierre, 2011). St-Pierre, Cobanov, and Schnitkey (2003) estimated the effect of heat stress on three aspects of pig production in the USA, namely decreased performance, increased mortality and decreased reproduction, to give rise to annual losses of approximately €250 million, with the finishing pig stage specifically equating to €196 million.

Due to the possibility of these large losses at extreme temperatures, pig housing design sometimes includes the capacity to supply extra cooling when required during the year via water misting (Santonja et al., 2017). This type of cooling system works on two principles of heat transfer, namely evaporation and convection. Evaporation uses the surrounding heat to transform water droplets into vapour, hence reducing the surrounding air temperature, whilst convection created by the velocity of extract air passing over the pigs aids the removal of heat and vapour before the pigs actually get wet. However cooling systems can potentially fail, particularly nozzles can block, resulting in the vapour not being produced correctly. As a result, water may reach the floor area with the negative consequences of not sufficiently cooling the internal air temperature and potentially providing an unsafe slippery floor (Baxter & Mitchell, 1977; Christion & Farmer, 1983). Therefore, alternative approaches to building design for finishing pigs are required, while maintaining current construction utility and maintenance costs.

In building design, the term 'passive' is used when studying how the natural conditions can be exploited to enhance the sourcing of heat and light from the sun and cooling and ventilation from the wind. The terms 'sustainable' or 'renewable' are associated with 'energy efficient' solutions to reduce energy costs within a building, but such solutions often require a form of energy to run the associated technology, such as controls and pumps, that enable the device(s) to reduce overall energy consumption. For this reason, engineers argue that passive design techniques should always be explored before sustainable solutions are incorporated, as an adaptation that increases running costs and/or carbon