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PREDICTION OF INDOOR CLIMATE IN PIG HOUSES

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ABSTRACT

To predict indoor climate in pig houses, design and management conditions have to be taken into account. Heat loads are high, and vary with live weight and animal production. Ambient air is often supplied directly into the room without preheating. Variable temperature set points are widely used to provide a warmer environment for young than for older pigs. Temperature control is maintained by supplying variable airflow rates, and minimum ventilation is limited by CO2 or humidity control.

StaldVent is a pc program that helps manufacturers, advisors and engineers, to design ventilation and heating systems, including selection of components, for which performance test data are available. Using StaldVent resulting yearly indoor thermal climate, air quality and energy consumption, may be determined for different temperature strategies.

In this paper the heat production algorithms used in StaldVent are discussed. It is illustrated how the room climate and air quality may be simulated over time and how the energy consumption may be analyzed at the design stage for different control strategies.

KEYWORDS: Heat production, pig houses, ventilation, heating systems, energy consumption, computer software.

Introduction

In order to obtain a good climate for the pigs and a pleasant working environment for the farmers, suitable selection of equipment for ventilation and heating systems are essential. For easier selection and optimization of pig house ventilation and heating systems the computer program StaldVent was developed (Morsing et al., 1997).

To predict indoor climate in pig houses, a number of special systems and management conditions, have to be dealt with. Both sensible and latent heat loads are high, and increase in many cases with time, as the pigs grow. Ambient air is often supplied directly into the room without preheating. Variable temperature set points are widely used to provide a warmer environment for young than for older animals. Temperature control is executed by supplying variable airflow rates, and minimum ventilation limited by CO_2 concentration and/or humidity control.

In this paper the heat production algorithms used in StaldVent are discussed. It is illustrated, how the room climate and air quality may be simulated over time and, how the energy consumption may be analyzed, at the design stage for different control strategies.

MATERIALS AND METHODS

The management strategy of a pig facility is essential for the ventilation system. Information about number and weight of the animals must be known, in order to calculate the required ventilation and supplemental heating capacity. The basic issues in these calculations are the total heat loss from the animals and how it is distributed on sensible and latent heat. StaldVent contains standard heat production values for different animal species including pigs.

HEAT AND MOISTURE PRODUCTION

In StaldVent the total heat loss as function of weight is used as basis for calculating the total heat production for weaners and growing/finishing pigs. The algorithms are based on work done by Strom & Feenstra (1981) and later adopted by CIGR (1984). CIGR (1992) introduced the feeding level as a additional parameter for calculating the total heat production. In CIGR (2002) tabulated values for feeding levels were also introduced.

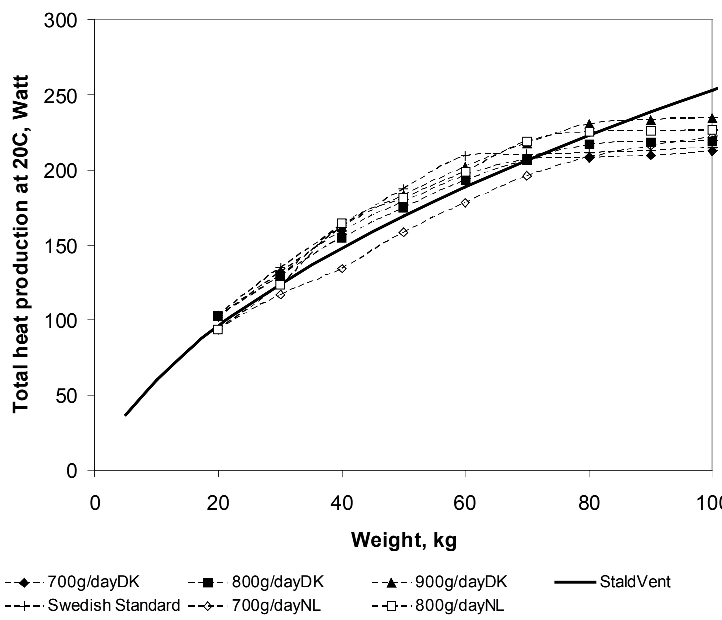

Figure 1. Total heat production for growing finishing pigs. The solid line is calculated by use of algorithms from StaldVent. The dotted lines are calculations at different feeding levels, by use of algorithms proposed by CIGR(2002).

In figure 1 the calculated total heat production for pigs at different weight is shown. The solid line is calculated by use of algorithms from StaldVent. The dotted lines are calculations by use of algorithms from CIGR (2002). It is seen that the total heat production by use of StaldVent is of the same order as the total heat production by use of CIGR (2002).

As described in CIGR (2002) it may be convenient to specify the total heat production as Heat Productions Units (HPU). One HPU corresponds to 1 kW total heat production at 20°C. The division of total heat in sensible and latent heat is strongly dependent of inside temperature, and StaldVent uses the algorithms introduced by Strom & Feenstra (1981). Figure 2 shows StaldVent's calculated total and sensible heat production in HPU as a function of indoor temperature.

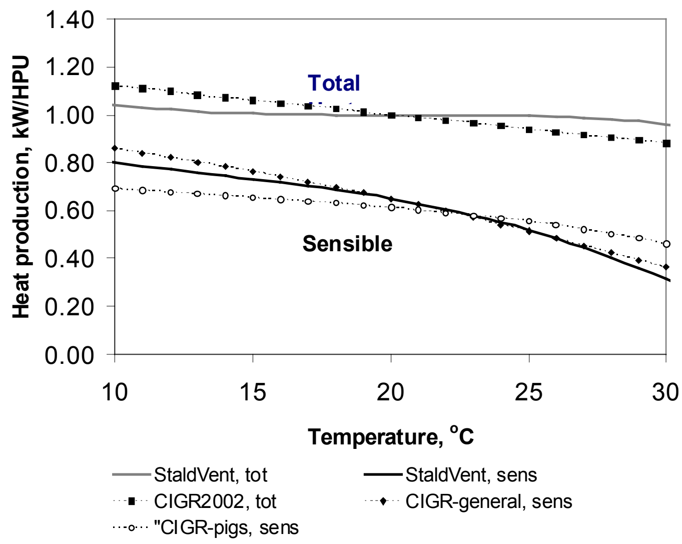

Figure 2. Variation with room temperature (ºC) of sensible and latent heat from pigs (temperature is the sensible heat, humidity is the latent heat, energy is the sum of sensible and latent heat)

During the last decade, the total and the sensible heat production has been discussed on animal and room level. The sensible heat production on room level is dependent on how much energy is used for evaporation of water from floor, manure etc. In figure 2 the suggestions by CIGR (2002) are shown together with the values used in StaldVent. The basis for the CIGR (2002) curves is mainly data collected in the temperature range 15-25°C.

Until more data outside the 15-25°C range is available, StaldVent uses the heat and moisture production given by Strom & Feenstra (1981) to calculate the heat load from the animals.

DESIGN MAXIMUM AND MINIMUM AIR FLOW RATE VENTILATION

StaldVent estimates the maximum and minimum airflow rate on the bases of heat, moisture and CO_2 production from the pigs. Furthermore, it calculates the additional heat energy, needed to maintain air quality during cold weather. On this basis, system components are selected that meet the thermal requirements for optimum pig production as described by Morsing et al. (1997).

StaldVent is primarily developed to handle premanufactured exhaust and air supply units for which performance test data are available. StaldVent calculates the ventilation rate that is obtained in the operation point for different control strategies (Morsing & Strom, 1992). Negative pressure ventilation systems with diffuse air intake may also be handled, e.g. taking supply air from the attic through porous insulation material. The program also handles selection of heating equipment e.g. heating pipes, ribbed pipes, etc.

Algorithms from the equipment test reports e.g. as described by Pedersen & Strom (1995) may be chosen for the calculations.

PREDICTIONS

StaldVent predicts indoor climate, by solving the steady state energy balance for a pig house, using hourly averages for set points and local weather (figure 3).

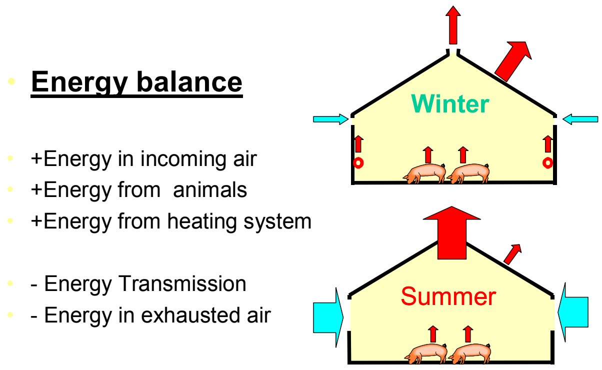

Figure 3. StaldVent solves the energy balance using hourly averages for set points and local weather.

The required ventilation and heat capacity, as well as the room climate, air quality and expected energy consumption throughout the year, as the result of different control strategies, may thus be analyzed at the design stage.

ROOM TEMPERATURE

Disregarding accumulation, room temperatures in pig houses are always higher than ambient due to the high sensible heat loads form the animals. For a pig house located near Aalborg (56 °N, 10 °E) in Denmark, the cumulated ambient temperature distribution is shown in figure 4.

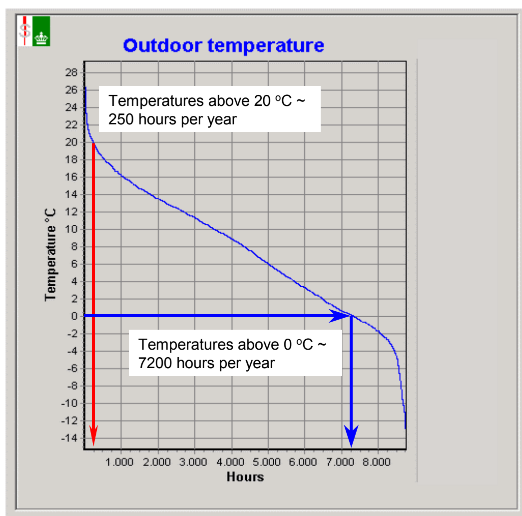

Figure 4. Cumulated ambient temperature in a year at Aalborg, Denmark.

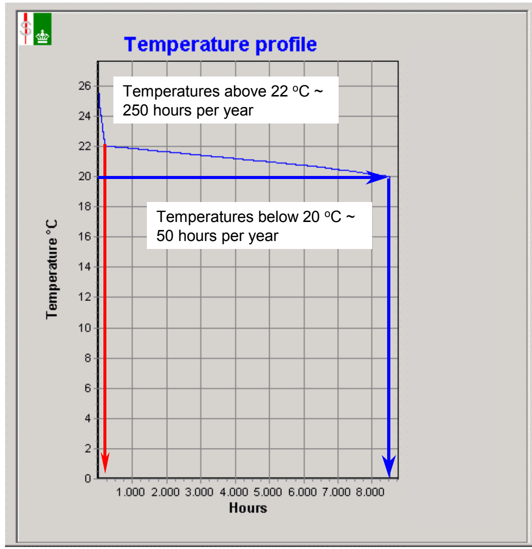

Figure 5. Cumulated indoor temperature in a year in a pig house near Aalborg, Denmark.

Temperature set point is lowered from 22 °C to 20 °C as the pigs get heavier.

The ventilation systems in Denmark are designed to limit room temperature to maximum 25 °C, at an ambient temperature of 20 °C. At higher ambient temperatures, the room temperature will be higher. At ambient temperature below 20ºC, the ventilation system will gradually be able to maintain a lower set point temperature. Figure 5 shows the predicted cumulated room temperature in a typical Danish pig building where the pigs arrive at a 30 kg and leave for the slaughterhouse at 90 kg average live weight.

The prediction takes into account the growth of the pigs and the associated varying heat loads at the room temperatures maintainable by the selected ventilation and heating system.

Assuming the fairly high set points of 22 °C at arrival of 25 kg pigs falling to 20 °C as the pigs grow to 95 kg, it is seen that temperatures above 22 °C are to be expected for 250 hours per year.

AIR QUALITY

CO_2 concentration in the room air is often taken as an indicator of air quality in pig house as in other buildings. A maximum limit of 3000 ppm is recommended for pig house (CIGR 1994).The cumulated CO_2 concentration in the pig house is shown in figure 6. At the temperature set point of 22/20 °C the CO_2 concentration limit is exceeded on average 1000 hours a year and measures should thus be taken to improve the air quality.

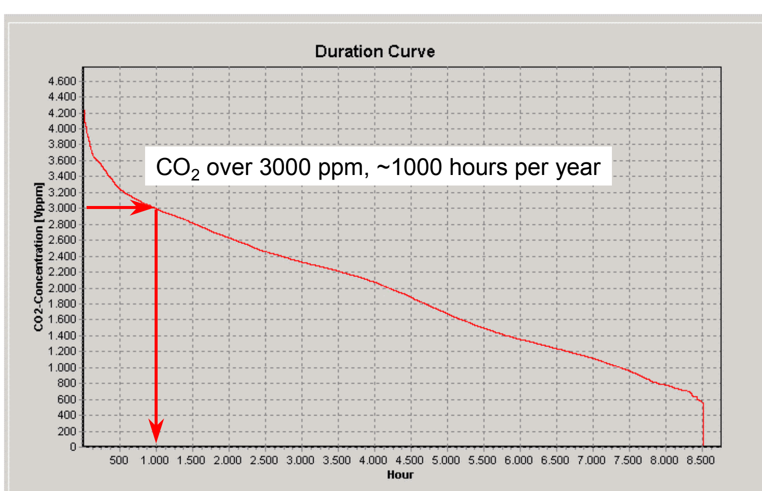

Figure 6. Calculated cumulated indoor CO_2 in a year in the pig house located near Aalborg, Denmark with temperature set point 22/20°C.

The effect of lowering the set point to 18/16 °C is a dramatic reduction from an average of 1000 to 50 hours with CO_2 concentration exceeding the 3000 ppm limit (figure 7).

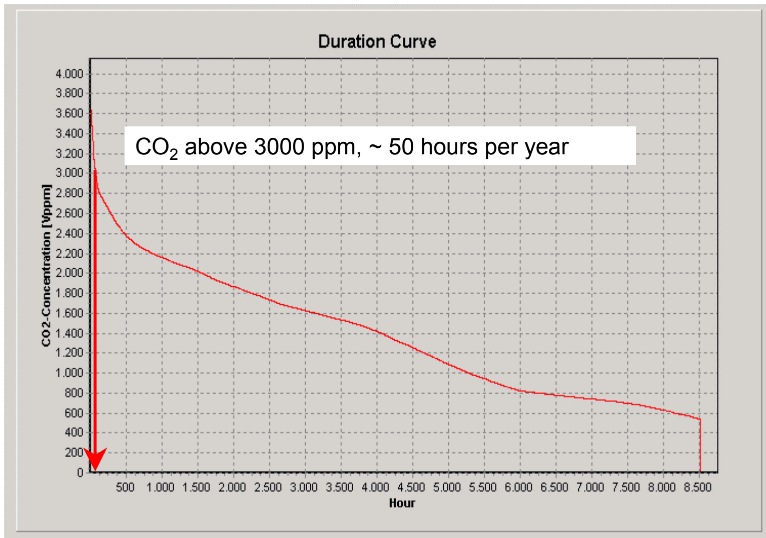

Figure 7. Calculated cumulated indoor CO_2 in a year in the pig house located near Aalborg, Denmark with temperature set points reduced to 18/16°C.

In lowering the room temperature set point, care should be taken to cater for the thermal well-being of the animals, e.g. by a covered or well bedded resting area. The 1300 hours that the indoor temperature exceeds the 18°C set point in figure 8 is due to high ambient temperature that the ventilation system cannot compensate for even at full ventilation capacity.

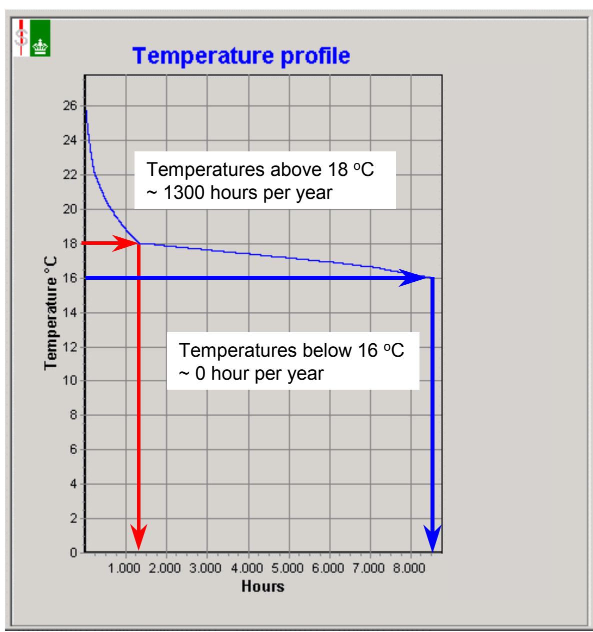

Figure 8. Calculated cumulated indoor temperature near Aalborg, Denmark when set point is lowered to 18/16 °C.

Energy consumption

StaldVent predicts the annual energy consumption put into heating and ventilation. This has opened up for analysis of the effect of different energy saving measures. This program option will especially be of interest to energy consultants. The effect of the two temperature set points is shown in table 1.

Table 1. Temperature set points, CO_2 concentration and energy consumption.

Temp. set point °C	Humid. max %	CO_2		Energy, kWh/year	
		Max. ppm	Hours > 3000 ppm	Ventilation	Heat
22 ->20	70->80	4064	1120	2261	3749
18 ->16	70->80	3614	96	5073	2774

By selecting a colder room air strategy, the recorded maximum CO_2 concentration is reduced somewhat but the main effect is the reduced duration of periods with CO_2 concentrations above the limit.

The lower temperature is reflected in lower energy consumption for heating while the improved air quality more than doubles the energy consumption for ventilation.

CONCLUSION

The prediction of indoor climate is a valuable tool to evaluate the heating and ventilation systems at the design stage. It provides data to evaluate the trade off between thermal climate, air quality and energy consumption for different temperature strategies. The program may be used to simulate the effects of different ventilation and heating systems and their control strategy to detect optimum combinations at a given location.

For manufacturers that export systems at a global scale the systems are to be adapted to local weather and management practices at the design stage.

Manufacturers of pig house ventilation systems use the program for planning purposes or for analysis of technical questions. StaldVent is also intended for technical studies at University levels, and at agricultural colleges to give the students a better insight into the climatic conditions in pig houses.

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