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Efficiency of climate control equipment in pig houses

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Introduction

Laboratory experiments have shown that environmental conditions (temperature, humidity, air velocity, etc) do influence the comfort and behaviour of animals and consequently growth, development, feed efficiency and health (1, 2, 3, 4). As a consequence, for some time efforts have been made to improve the environment in commercial livestock buildings. Thus many different types of buildings and techniques are actually used in the field (5). In countries with intensive pig husbandry and with high feeding costs, there has been a trend towards more confinement housing. More expensive pig houses with compartments, with mechanical ventilation systems, with heating systems and with automatic controllers are used. It would be expected that such buildings would give better production results compared to naturally ventilated, unheated buildings in which weather changes of wind velocity, wind direction and outside temperature would have more effects on the internal environment (6). Because of the costs of today's automatically controlled mechanical ventilation systems, there are doubts about the economics of their beneficial influence on production results. From statistical analysis of field data, houses with mechanical ventilation systems using automatically controlled exhaust fans were recently found to give no better mean production results than natural open-ridge systems (7, 8, 9, 10). To explain this, components of the mechanical ventilation system, namely the fan and the proportional controller, were withdrawn from their field situation and were analysed in a laboratory test installation (11). The objective of this article is to examine the effectiveness of existing mechanical ventilation systems relative to that of natural ventilation systems, as they are operated in a pig house under practical conditions.

Methods and materials

In Belgium there is a unique structure of contractual farming under the Belgian Farmers' Association (Belgische Boerenbond) which has led to the installation of identical pig houses throughout the country. Buildings that were installed within the same period of time were identical as regards design, dimensions, materials, construction, air inlet and outlet arrangements and wind baffles. This made it possible to select a large number of identical buildings for taking measurements. The naturally ventilated buildings had air inlet vents and/or outlet vents which could be controlled manually (Figure 1). The propeller fan in the mechanically ventilated buildings was placed in a standard chimney in the roof (Figure 1) and the speed was controlled by means of the control algorithm shown in Figure 2.

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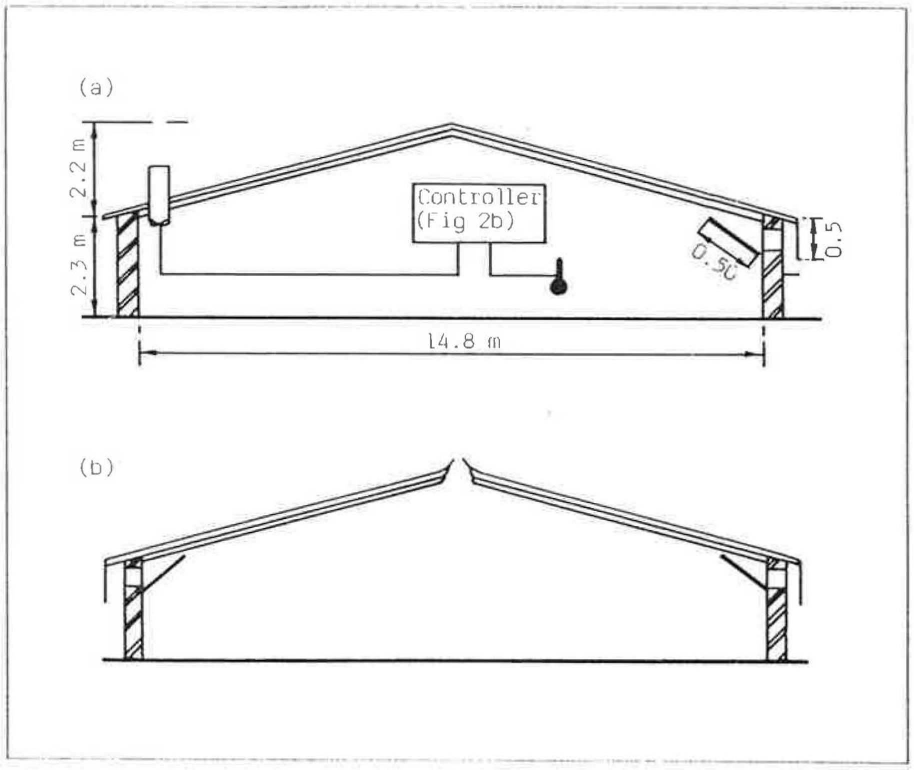

Figure 1 (a) Mechanical ventilation system, exhaust fan and proportional controller. Length of house: 19 m. (b) Natural ventilation system, open ridge. Inlets on both side walls to permit ventilation from wall to wall when there is no buoyancy effect in summertime.

In the piggeries the all-in/all-out system was used and most pigs were Belgian Landrace. All animals within the same period of time received the same commercial food. To eliminate as far as possible the influence of the individual farmer, only buildings of farmers with comparable good production results (better than the mean value) were chosen. The internal temperature was measured at the location of the controller temperature sensor in a mechanically ventilated building or in the middle of the piggery in a naturally ventilated building. The setpoints of the controller (minimum ventilation rate and desired inside temperature) were recorded and outside temperature was measured using an integrated circuit (Analog Device 590). The number of days from the beginning of the fattening period was noted. In total, 86 buildings were measured for the years 1983 and 1984. All the buildings were visited 4 or 5 times during the fattening period to assess the climatic conditions and the operation by the farmer. Of the 86 buildings measured, 25.6% were equipped with a mechanical ventilation system, a heating system and automatic controllers and with compartments in the building (type A). 16.2% of them had a natural ventilation system, no heating system, manual control and no compartments in the building (type B). Thus the most expensive type of pig house (type A) is compared with the low cost type of pig house (type B). Some general information about these pig houses is given in Table 1.

To acquire more information about air flow control through the building, a field measurement installation was used in three different piggeries. Inside temperature (accuracy 0.1 °C), outside temperature, voltage to the fan and the ventilation rate through the building (accuracy 100 m³/h) were measured over a 12 hour period with a sample time of two minutes. For air flow rate, the value stored by the data-logger every two minutes was a mean value of 60 samples (Figure 3).

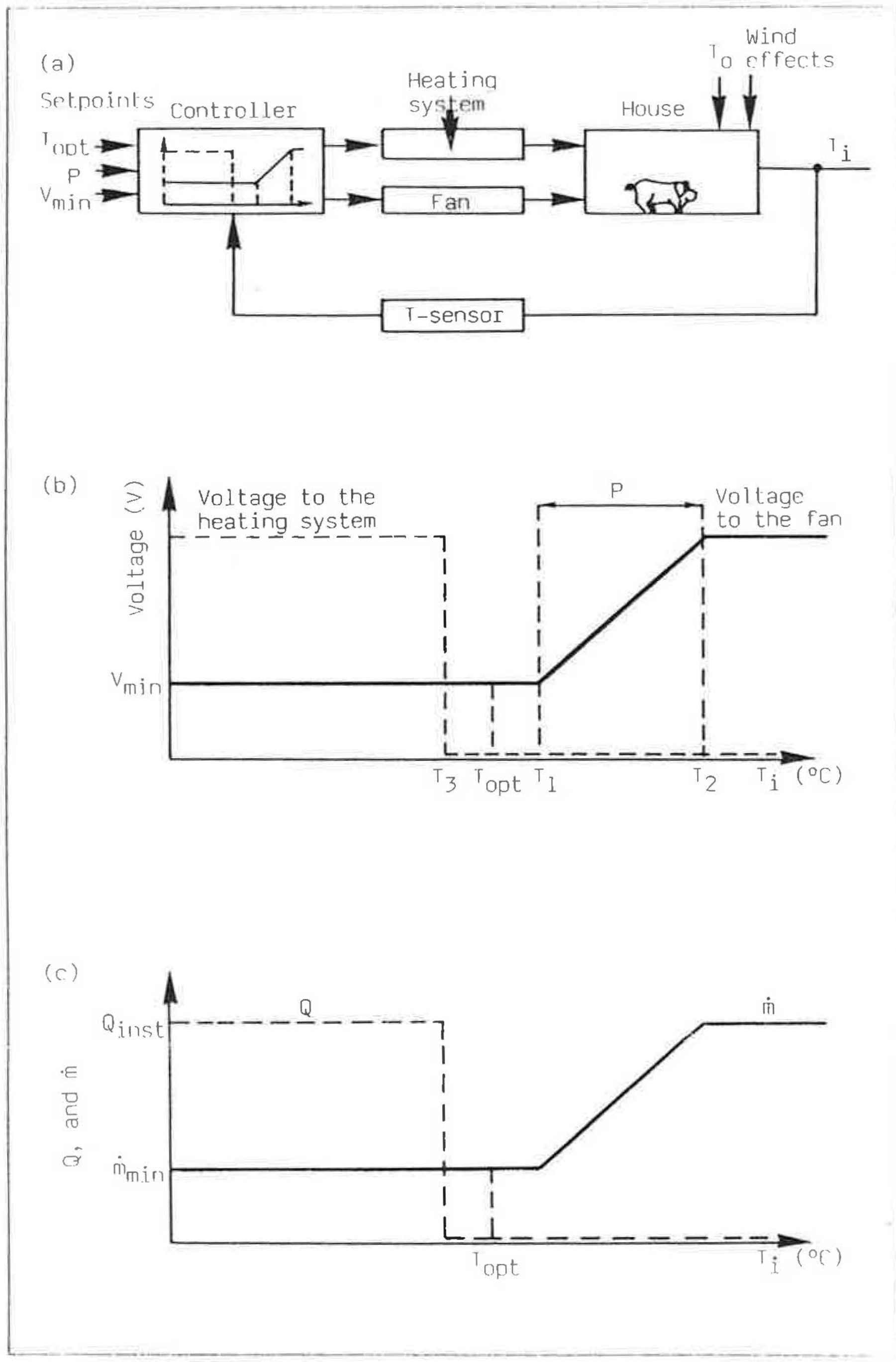

Figure 2 (a) Controller and house relationships. (b) Controller characteristics with three different setpoints: T_{opt}, V_{min} and p (c) Desired controller function for artificial heat supply (Q) and air flow rate (m) in a livestock building.

Key to symbols used in Figures 1–12

m	Ventilation rate through the pig house
N	Number of observations
P	Proportional band of the controller (Figure 2)
T_i	Measured inside temperature (°C)
T_o	Measured outside temperature (°C)
T_{opt}	Controller's setpoint for inside temperature (°C)
T_1, $_2$ or $_3$	Characteristic points in the controller's ventilating characteristic curve (Figure 2)

Results and discussion

Results of measured inside and outside temperatures for the two types of building are given in Figures 4 and 5. The mean value of inside temperature, measured five times during the fattening period and this over a period of two years, is only 0.8 °C higher in the more expensive buildings compared to the low-cost building. The standard deviation is only 0.8 °C smaller in building type A. The relationship between inside and outside temperature can be explained from steady-state analysis (12). It can be concluded that the differences in measured inside temperature between building types A and B can be neglected. This would indicate that the mechanical ventilation system and the heating system do not have a high influence on inside temperature. Therefore one must consider how this system of climatic control is achieving the installed setpoint for inside temperature. Figure 6 gives the measured inside temperature as a function of the controller's setpoint for inside temperature in mechanically ventilated and heated buildings with compartments. By using steady-state analysis it can be explained that in such a building with free-cooling system, inside temperature can rise above the controller's setpoint because of high internal heat production (12). If, on the other hand, inside temperature is decreasing below the controller's setpoint (Figure 6), this would indicate a malfunction of the heating system or poor control of the (minimal) ventilation rate (Figure 2).

From the ventilation rates measured in the field, it can be concluded that there was not good control of the air flow rate through the building (Figures 7 and 8). This can be explained by the combination of this controller (Figure 2) with the characteristics of a propeller fan (11). It can also be seen (Figure 9) that the wind effect does increase the ventilation rate above the value desired by the fan controller.

From Figure 10 it can be noticed how the controller's setpoint of inside temperature compares in practice with the advice that is given to the farmers.

Table 1 Characteristics of pig housing types.

	Mechanical ventilation system, heating system, with compartments		Natural ventilation system, no heating, no compartments	
	Building type A		Building type B	
	Mean	S.D.	Mean	S.D.
Mean floor areas (m²)	375	95	236	105
Mean volume (m³)	1233	231	705	378
Number of animals	364	79	263	139
Pigs per m²	1.25	0.14	1.18	0.13
Warm area (%)	49	23	44	19
Starting weight per animal (kg)	21.0	1.0	21.3	0.7
Final weight per animal (kg)	102.3	3.7	101.2	3.8
Feed conversion ratio	3.38	0.16	3.47	0.12
Growth rate (g/day)	580	48	574	31
Mortality (%)	3.5	1.9	4	2.3
Duration of fattening period (days)	141	12	140	6

The mean inside temperature in the buildings with mechanical ventilation systems is a little bit higher than in the naturally ventilated buildings (Figures 4, 5, 11 and 12). The standard deviation is only 0.7 °C greater over the fattening period in a naturally ventilated pig house compared to a mechanically ventilated one with a heating system (Figures 11 and 12).

Conclusion

The ventilation system is considered to be one of the most important factors influencing other variables (13, 14). The main objectives of the ventilation system are to control gas concentration, temperature and humidity inside the building (15). To do so, two basic functions have to be realised: firstly, efficient control of the air flow rate through the building and secondly, good control of the air flow pattern (16, 17, 18). Based on the observations reported in this article, one has to conclude that the proportional controller combined with a propeller fan does not achieve better inside temperatures in today's pig houses. There is no good control of the air flow rate through the buildings and consequently there will be no good control of the air flow pattern (19).

Before one can introduce more sophisticated control algorithms in the field, more knowledge is required to achieve good control of the air flow rate through the building. On the other hand, it can be noted that a controller with setpoints to be installed manually, is not operated in a good way. Hence the proposed optimal climatic conditions for the best pig production results (see the introductory section) are not yet realised in the field.

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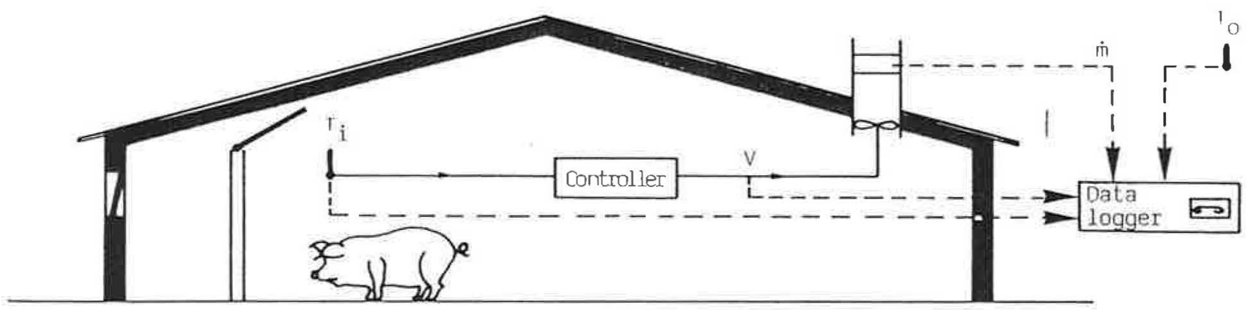

Figure 3 Installation to measure inside temperature in relation to the ventilation rate in a type A building.

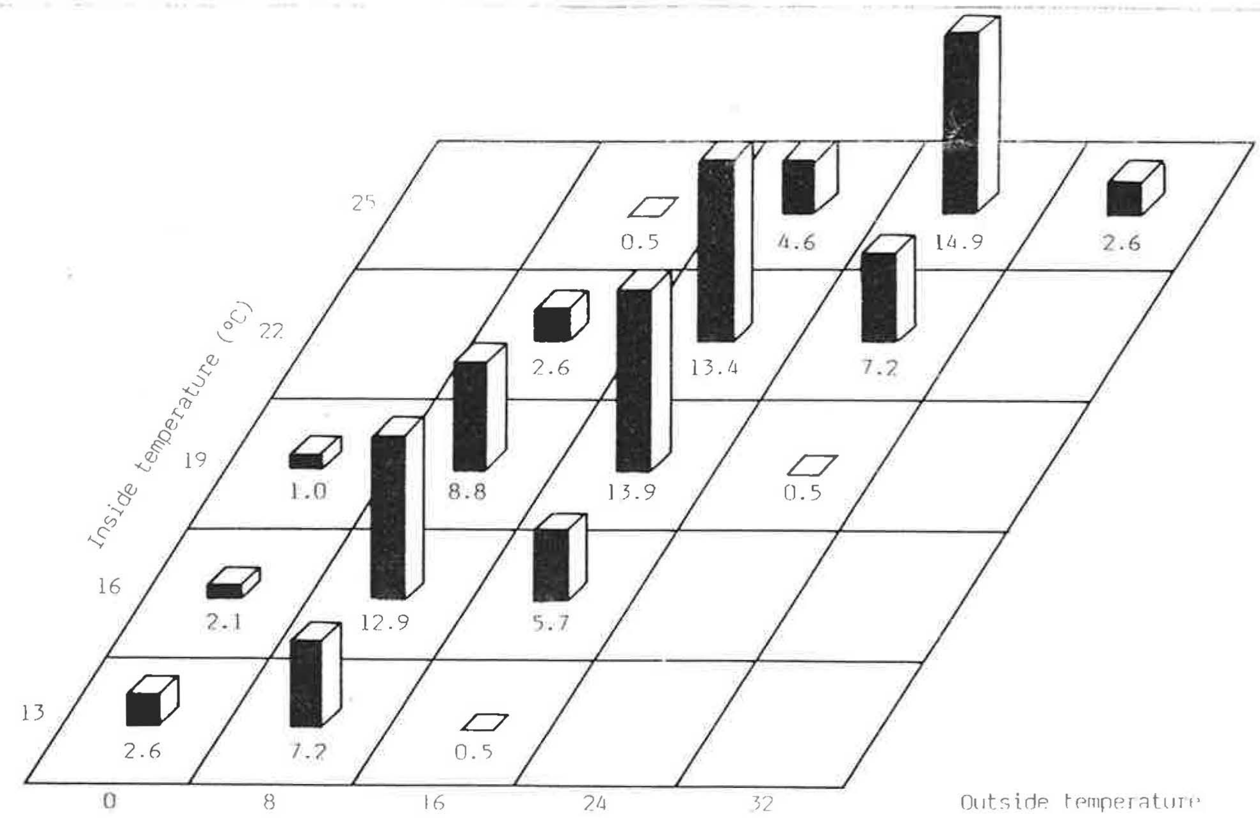

Figure 4 Percentage block chart of the measured inside temperature versus outside temperature for naturally ventilated buildings without compartments and without a heating system. $T_{i\,mean}$ = 20.4 (S.D. = 4.2) °C ; $T_{o\,mean}$ = 14.4 (7.5) °C ; N = 176.

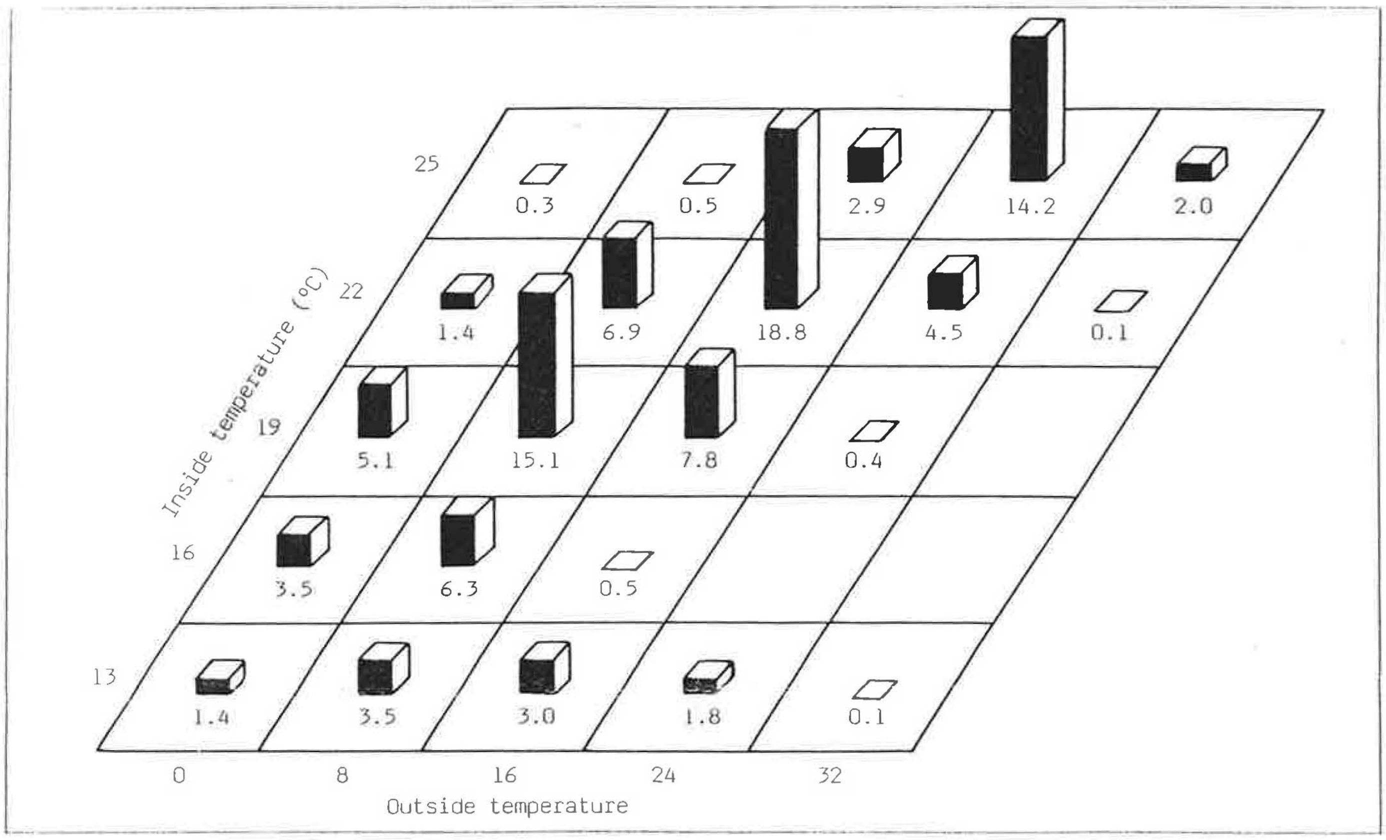

Figure 5 Percentage block chart of the measured inside temperature versus outside temperature for mechanically ventilated buildings with compartments, with a heating system. $T_{i\,mean}$ = 21.2 (S.D. = 3.4) °C ; $T_{o\,mean}$ = 13.6 (S.D. = 7.7) °C ; N = 1368.

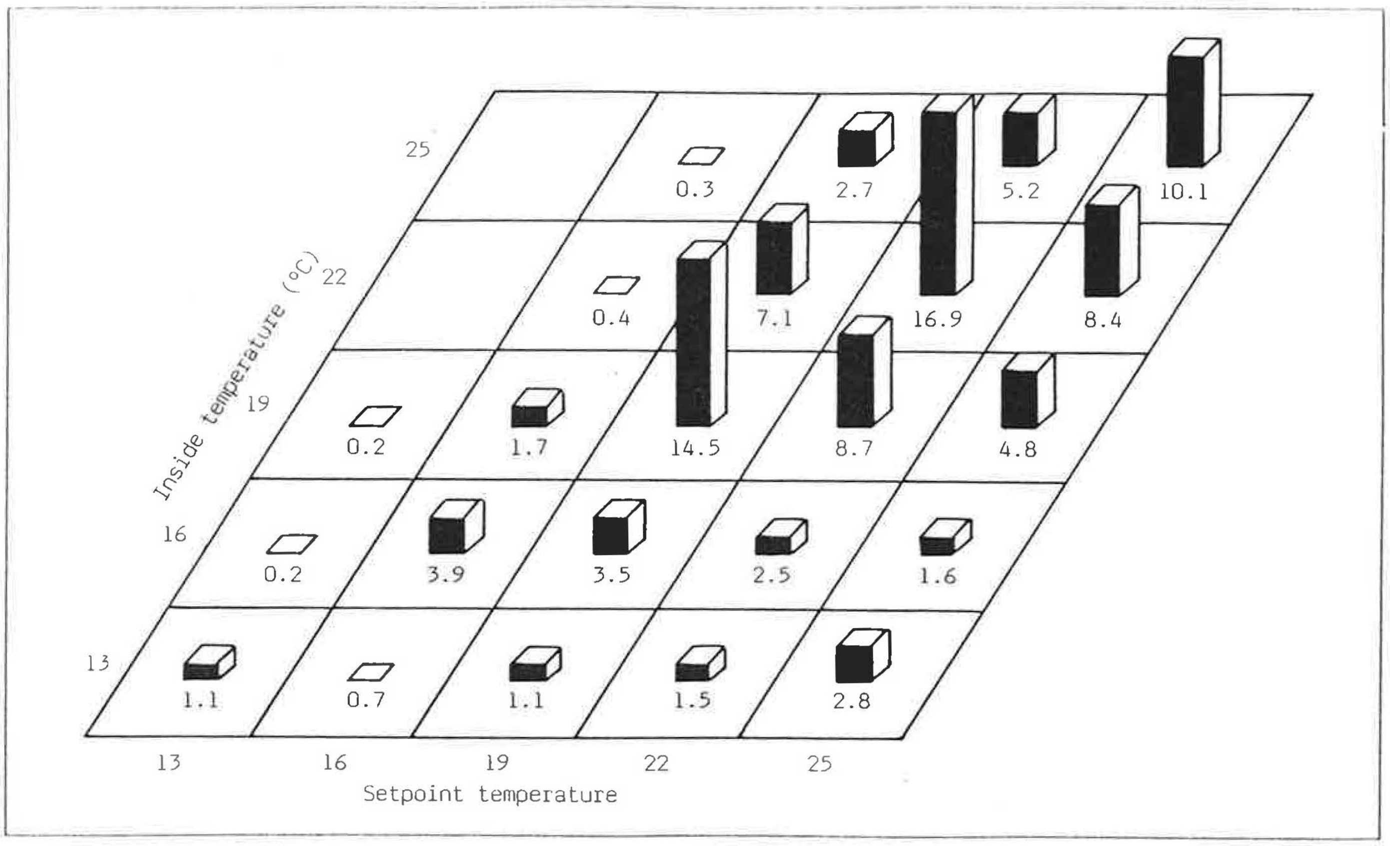

Figure 6 Percentage block chart of the measured inside temperature versus setpoint temperature. Mechanically ventilated building with compartments and with a heating system. $T_{i\,mean}$ = 21.1 (S.D. = 3.4) °C ; $T_{setpoint\,mean}$ = 21.9 (S.D. = 3.4) °C ; N = 1065.
Note 17 observations not indicated, where group size > 26 (Z=26).

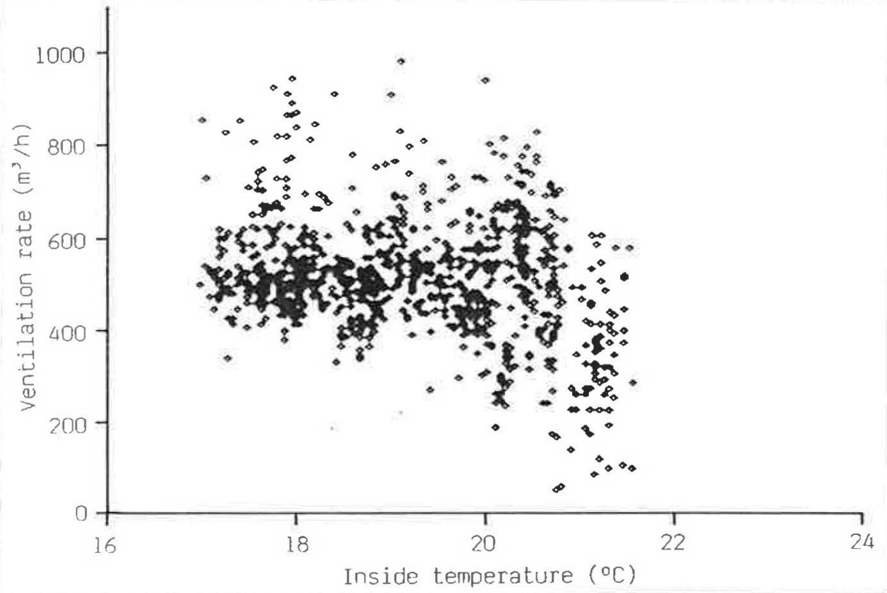

Figure 7 Measured ventilation rate as a function of inside temperature in a type A building with 90 animals of 25 kg each.

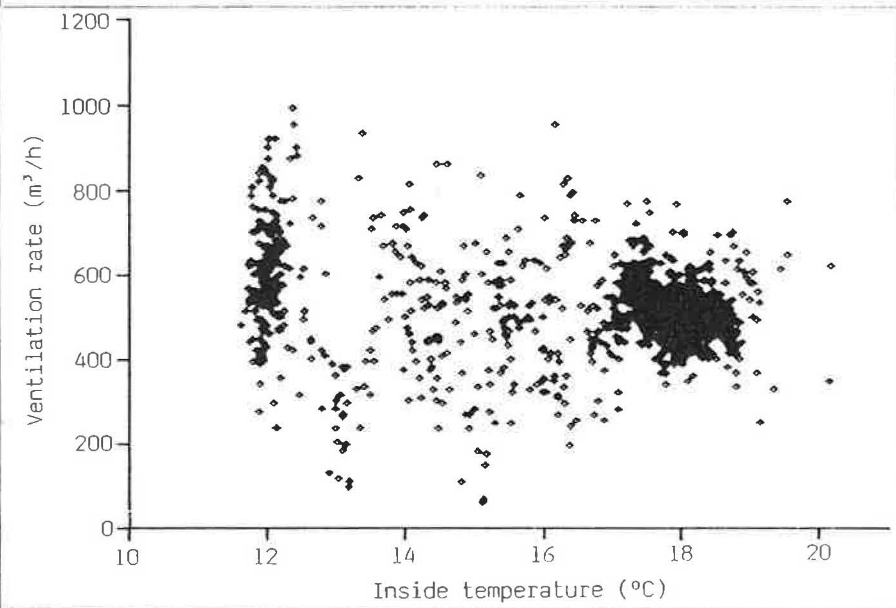

Figure 8 Measured ventilation rate as a function of the difference between inside and outside temperature in a type A building.

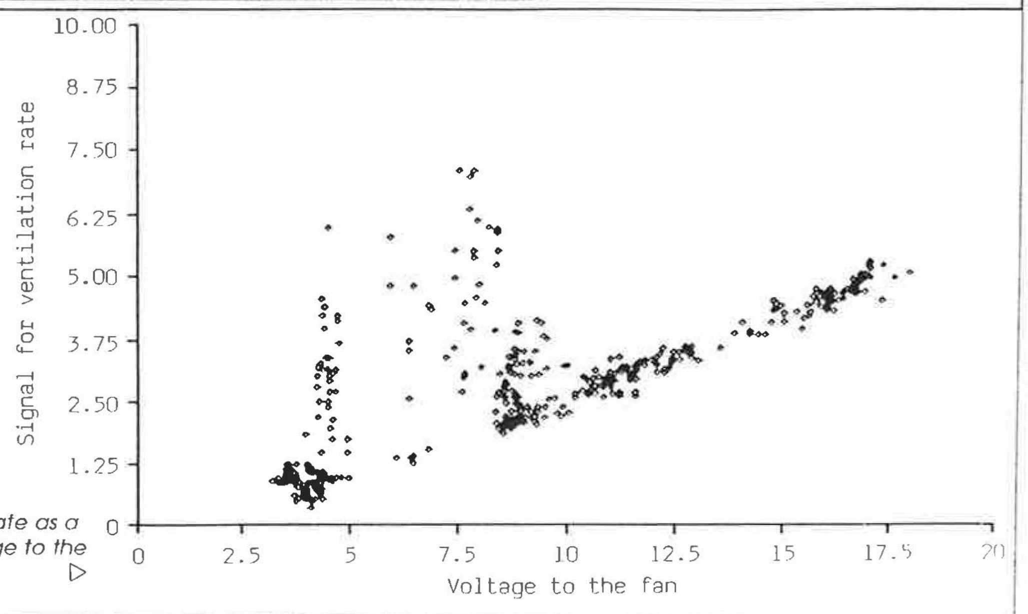

Figure 9 Measured ventilation rate as a function of the measured voltage to the fan in a type A building.

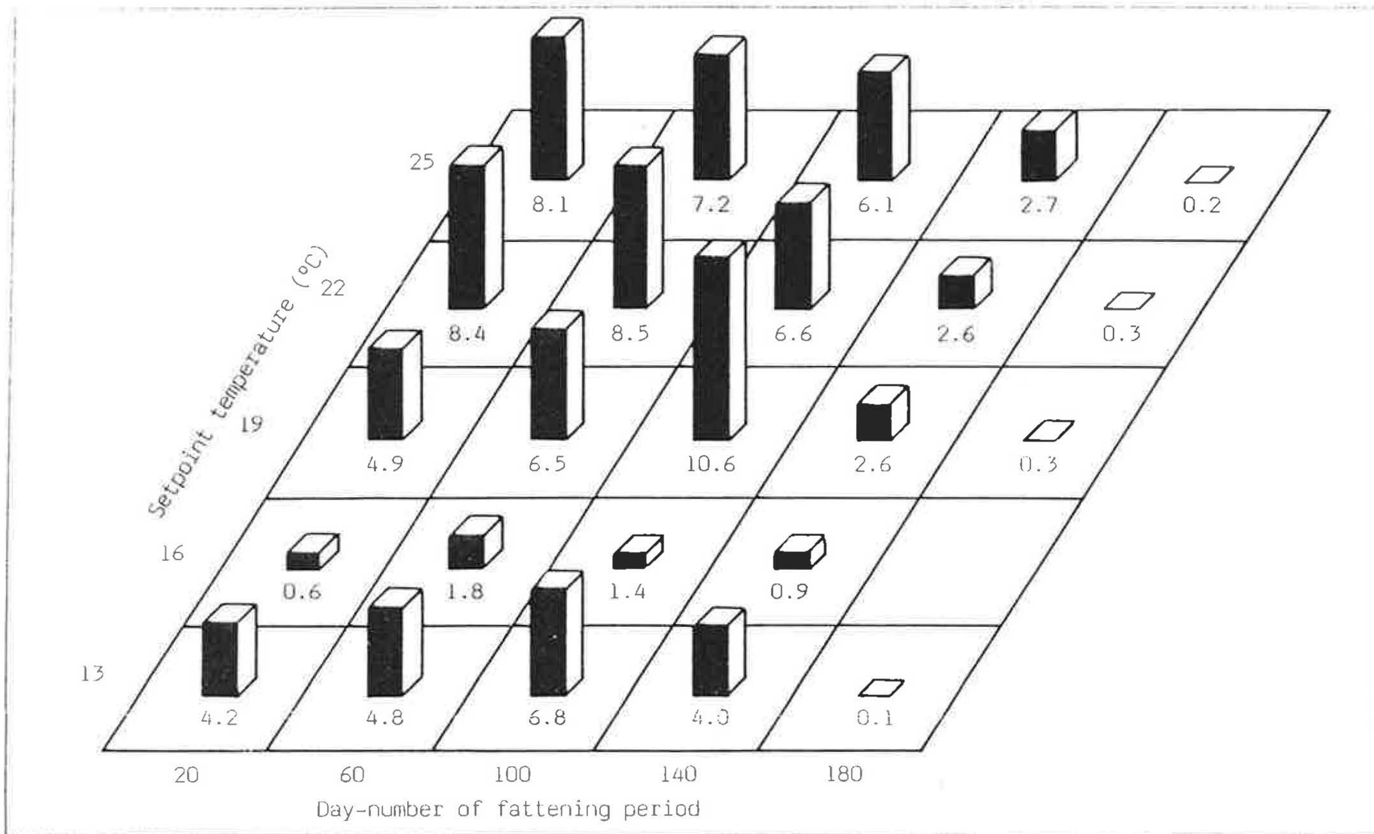

Figure 10 Percentage block chart of the setpoint temperature as a function of the daynumber of fattening period for mechanically ventilated piggeries with compartments and with heating systems. $T_{setpoint}$ mean = 22 (S.D. = 3.5) °C ; N = 985.

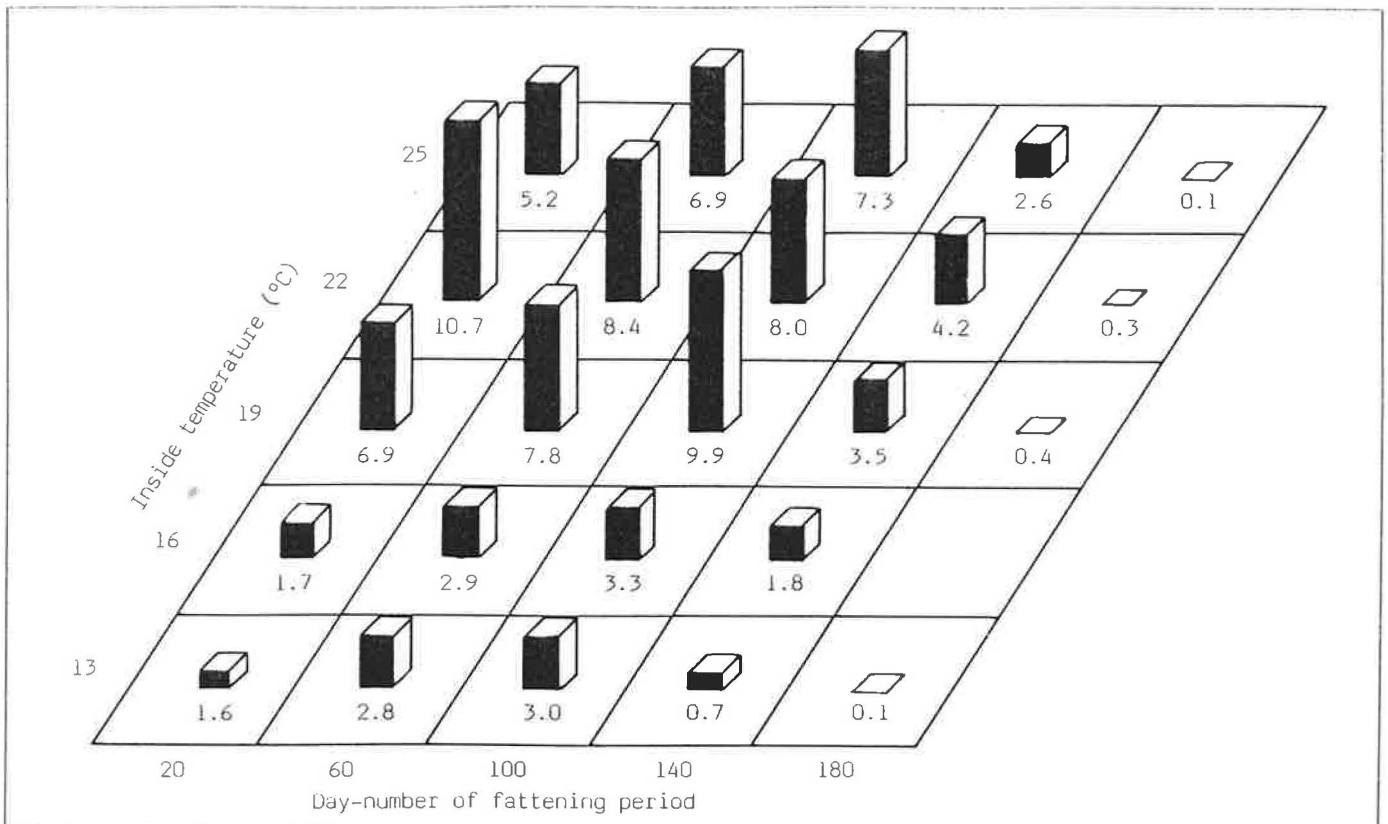

Figure 11 Percentage block chart of the measured inside temperature as a function of the daynumber of the fattening period in a mechanically ventilated piggery with compartments and with a heating system. $T_{i\,mean}$ = 21.4 (S.D. = 3.5) °C ; N = 985.

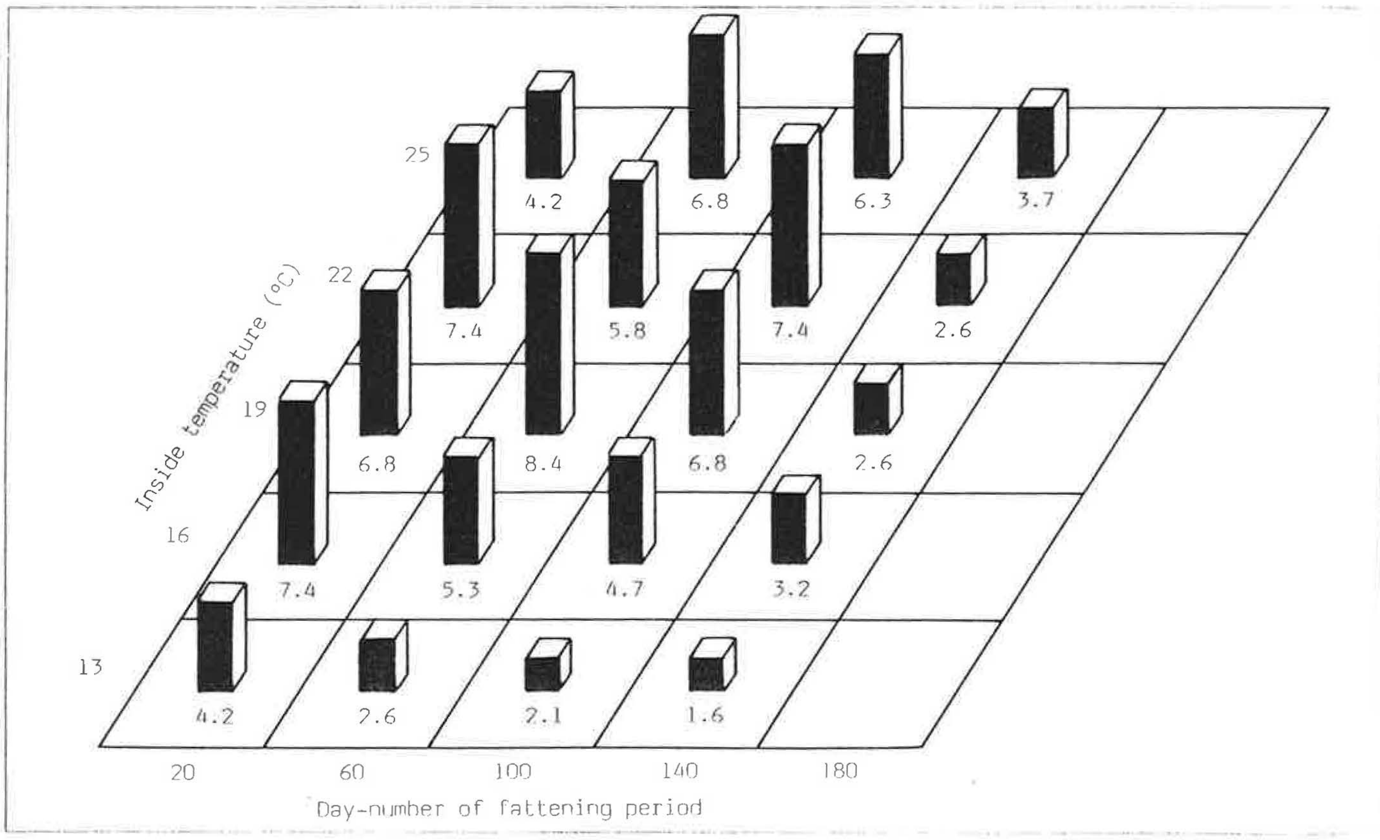

Figure 12 Percentage block chart of the measured inside temperature as a function of the daynumber of the fattening period in a naturally ventilated piggery without compartments, no heating system. $T_{i\,mean}$ = 20.3 (S.D. = 4.2) °C ; N = 171.

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