WARMING OF PIGLETS RESTING PLACES BY AIR HEAT PUMP IN DEPENDENCE ON OUTSIDE AIR TEMPERATURE

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Abstract. Alongside with traditional energy resources such as fossil fuel in all its variety – coal, wood, petroleum products, fuel gas – interest is raising about low temperature heat source usage, when heat pump is transforming it to the required higher temperature. The aim of the research is to ascertain in the conditions of production the suitability of the use of the outside air heat pump for providing energy for heating resting places of piglets. Researches were made in conditions of production during the period June 2009 till December 2009 in the pigsty with 96 farrowing pigpens, where in the resting places of piglets panels (heated with the warm water) are built-in. During the experiments amount of used heat energy for heating the floors was counted with ultrasonic heat meter, amount of electric energy needed for driving the compressor and electric boiler was registered with electric energy meters. Results of the experiments showed that energy demand depends on lactating-farrowing period of a sow and on outside air temperature. At outside air temperature below +10°C the surface of the evaporator intensively becomes covered with hoarfrost and to ensure required amount of heat energy electric boiler is being switched on, as result efficiency of the use of heat pump decreases. Decrease of intensive hoarfrost coverage is achieved by directing warm air of pigsty to the evaporators of a heat pump.

Keywords: heat pump, coefficient of performance, heating panel.

Introduction

Provision of heat energy demand in the intensive production of piglets is very important all over the year. Amount of heat energy depends on different factors, including construction of resting places of piglets, climatic conditions, and age of piglets. Alongside with traditional energy resources such as fossil fuel in all its variety – coal, wood, petroleum products, fuel gas – interest is raising about low temperature heat source usage, when heat pump is transforming it to the required higher temperature. A possibility of transformation of heat energy determines coherence [1, 2]:

$$COP = T_H \left(T_H - T_L\right)^{-1}, \tag{1}$$

where COP – coefficient of performance of a heat pump;
T_H – the highest (required for the user) temperature, K;
T_L – the lowest (heat source) temperature, K.

The higher temperature difference of heat source temperature and required for the user temperature, the smaller will be the *COP*. Forecast of the efficiency of heat pump performance can be based on two main considerations. Firstly, during the warm weather conditions at positive outside air temperatures outside air heat pumps are running at eligible high *COP*, on the average 3-4. Secondly, during the cold and frigid weather conditions, when *COP* of the heat pump dramatically decreases, it is hopefully to use outflow ventilation air of the pigsty as heat resource for heat transformation.

The aim of the research is to determine the suitability of application of outside air heat pump in conditions of production for heating resting places for piglets from the two points of view – technological regime of a farm and functional regime of heat pump.

Materials and Methods

For the performance of experiments one of the pig farm farrowing sow compartments with two sections was chosen. The consecutive technological rhythm at farm is realized with one week interval. The cycle in section from sow farrowing till weaning of piglets including cleaning and disinfection of section goes on for 7 weeks. There is a joint heat supply system with warm water circulation system for heating 96 panels of resting places. For the performance of experiments were set up two outside air evaporators beside the pigsty, compressor block with the automatized control panel inside the hall of the pigsty. The first testing cycle has been carried out during November 2008 [3]. The experiments during the year 2009 were performed under the improved methodology. Firstly, the operation of the heat pump was programmed by the temperature of the back-flow water within 36-38 ˚C. The switch off of the compressor is realized, when water achieves the maximum temperature 50 ˚C.

During the experiment amount of consumed heat energy for panel heating with precision 1 kWh was regularly counted with ultrasonic heat meter SONOMETER^{TM}1000 and simultaneously separately amount of electric energy consumed by compressor and electric boiler with precision 0.01 kWh was counted as well. If we know mentioned above measurements, we can determine efficiency of the heat pump using the following coherence:

$$COP = QP^{-1}, \tag{2}$$

where Q – amount of obtained heat energy, kWh;
P^{-1} – work consumed for heat pump operation, kWh.

During particular periods temperature of water (which is heating the panels) at start and end of the circuit was registered with HOBO data logger with precision 0.02 ˚C.

Results and discussion

During summer period experiments starting from the middle of June until the middle of September two cycles from farrowing of sows till weaning of piglets were passed. The average results about this period accordingly to the technological rhythm of the week are summarized in the Figure 1.We can see from the figure how power of heat energy is varying due to maintenance of necessary temperature level of the panels in the resting places of piglets, appropriate consumption of electric energy for ensuring heat energy, efficiency of the heat pump performance (*COP*) and outside air temperature. During the second period of the experiments from middle of September till the end of the 1st decade of December when outside air temperature declined under +10 ˚C intensive frosting of the evaporators started and for this reason electric boiler was operating frequently for ensuring required heat energy. Appropriate results are given in Figure 2. During this period the ways of the defrosting of the surface of evaporators were looked out.

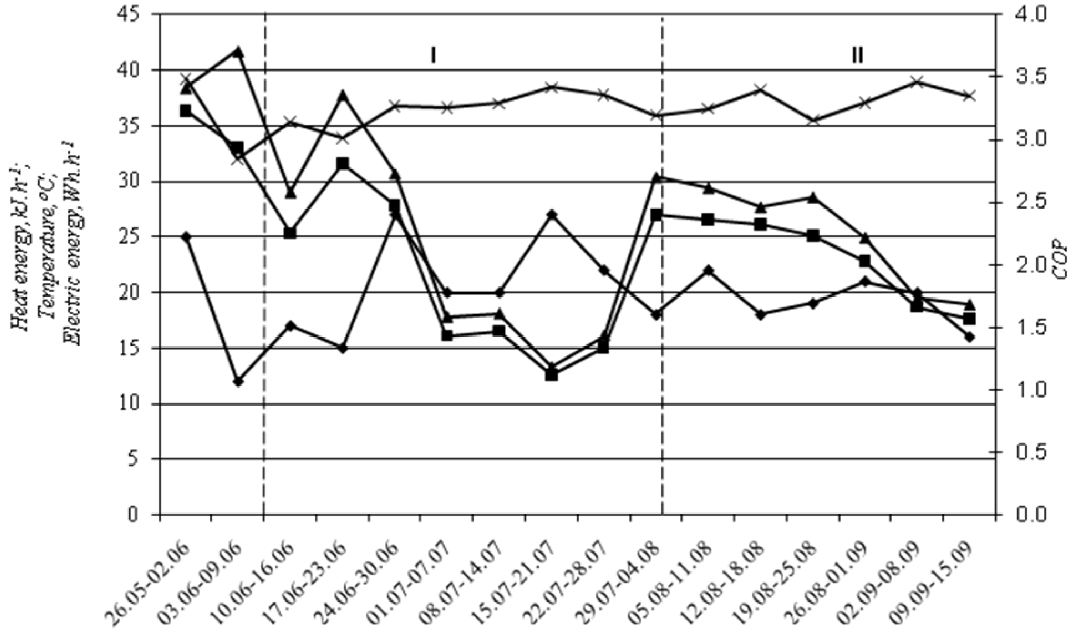

Fig. 1. **Average parameters of the heat pump operation by week intervals during 1st (I) and 2nd (II) farrowing cycle, which are assigned to one heated panel:**
T – air temperature, *Qp* – heat energy consumption, *Np* – electric energy consumption, *COP* – coefficient of performance of the heat pump

Evaluating results of the experiments from the farm technological regime point of view, some tendencies for ensuring heat energy for one resting place are seen in Table 1. Firstly, need of the heat energy demand is varying cyclic: at the sow farrowing period heat energy demand is the highest and then gradually decreasing until the weaning of piglets when minimum of energy demand appears. Secondly, heat energy demand is affected by outside air temperature. In June at the start of the first farrowing cycle, when outside average temperature was about 15 ˚C, heat energy demand for one panel heating was 120 Wh·h^{-1}. Heat energy decreased up to 40 Wh·h^{-1} at the period of the weaning of piglets. During the 2nd farrowing cycle (August till the middle of September) twenty four hours and period temperature fluctuations were very minimal and appropriate effect on the heat energy demand: 95-60 Wh·h^{-1}. In general the *COP* of the heat pump was stable as well, it was 3.25-3.30. During the 3rd farrowing cycle outside air temperature decreased gradually from 18 ˚C to 5 ˚C. Need of heat energy was ensured till the start of October (when only the compressor of the heat pump was operating) when outside air temperature was above 10 ˚C. When outside air temperature declined under 10 ˚C intensive frosting of the surface of evaporators started and electric boiler started being switched on. The *COP* of the heat pump decreased substantially wherewith.

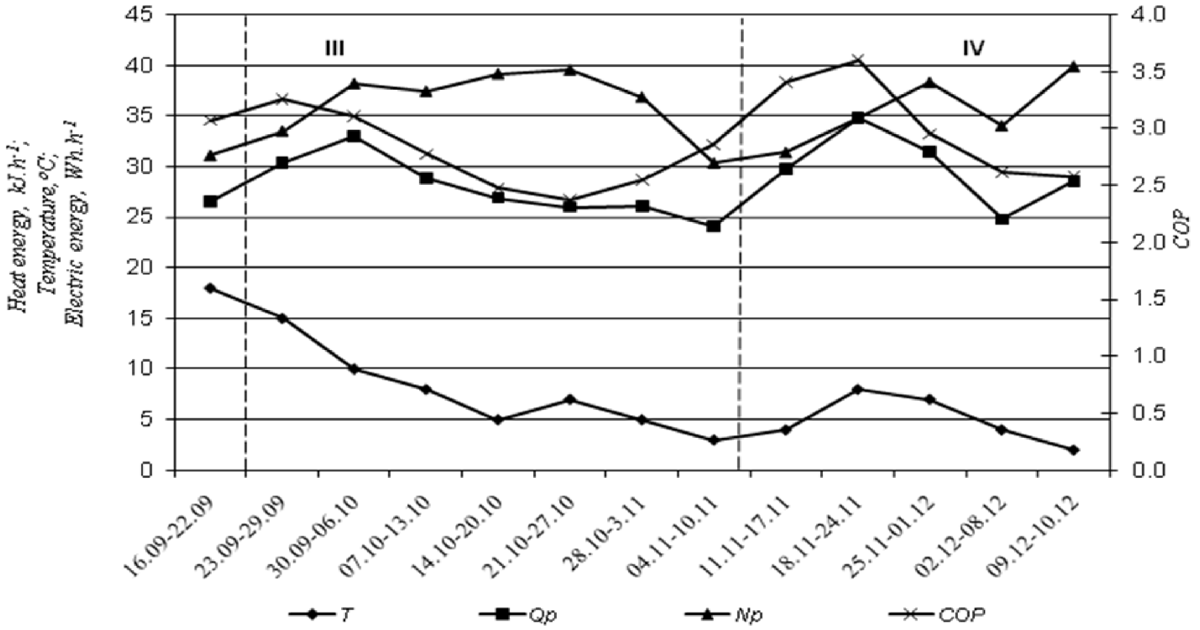

Fig. 2. **Average parameters of the heat pump operation by week intervals during 3rd (III) and 4th (IV) farrowing cycle, which are assigned to one heated panel:**
T – air temperature, *Qp* – heat energy consumption, *Np* – electric energy consumption, *COP* – coefficient of performance of the heat pump

To find possibilities and solutions of the prevention of intensive frosting of evaporators and wherewith maintaining the *COP* of the heat pump on the quite high level, during the autumn period were made train of experiments when outflow air of pigsty was breezed to the one of evaporators. Results of the experiment when outflow air of pigsty was breezed to the one of evaporators are generalized in Table 2.

Table 1

Amount of heat energy for ensuring required temperature of panel of resting places for piglets

Nr of the farrowing cycle	Period of time, month	Outside air temperature, ˚C	Use of heat energy, Wh·h^{-1}		*COP* of the heat pump
			At farrowing	At weaning of piglets	
1.	10.06-02.08	12-26	120	40	3.25
2.	3.08-22.09	18-22	95	60	3.30
3.	23.09-09.11	5-18	95	85	2.80
4.	10.11-10.12	2-5	125	-	3.00

When blowing outside air to the evaporator with intensity in average 1.5 m^3·s^{-1} achieved results was dependent on outside air temperature. At outside air temperature 10 ˚C when frosting of the evaporator was minimal, increase of heat power was up to 1 kW what in point of fact is a little bit more than power required for operation of ventilator – 0.5 kW. At outside air temperature 6 ˚C, increase of heat power achieved up to 3 kW. Insignificant increase of heat power still remained when outside air temperature was declining more, but it was not able to thaw the frosting of the surface of evaporator due to operation of compressor. Therefore around the evaporator screens were placed (Figures 3 and 4) and from the hall of the pigsty to the surface of the evaporator warmer air was supplied with temperature 7-9 ˚C what improved usage of heat. Positive effect with increase of power for 2.4-3.2 kW was still achieved at outside air temperature +2 ˚C.

Table 2

Results of experiments with airflow around the evaporator

Parameter	Unit of measurement	Outside air temperature +6 ˚C			Outside air temperature +2 ˚C	
		without ventilator	with ventilator	with screens	with screens	without ventilator
1	2	3	4	5	6	7
Heat energy	$kWh \cdot h^{-1}$	9.68	11.06	12.9	10.4	9.65
Consumption of the electric energy	$kWh \cdot h^{-1}$	4.00	4.24	5.1	4.4	5.18
COP of the heat pump		2.50	2.63	2.5	2.4	1.85
Maximal power	kW	9.4	12.4	13.2	10.8	8.5
Increase in power	kW	-	3.0	3.2	2.4	-

During the use of heat pump it was kept track of operating regime. Making the analysis of the switching on/off of the compressor, it is operational cycle depending on set up of back-flaw water temperature from 36 ˚C to 38 ˚C duration of the operation of compressor during the cycle becomes longer (Table 3). The same situation appears when outside air temperature declines until heat pump starts operating in uninterrupted regime without switching off. From the point of view of exploitation of heat pump it is preferable that durations and interruptions of the cycle would be longer. Mentioned above conditions contributes to defrost of the evaporator during the interruption of operation of the compressor at sufficiently high outside air temperatures.

Fig. 3. **Evaporator of the heat pump covered with screens during the supply of warm air**

Fig. 4. **Covering screens are opened. Plates of the evaporator almost thawed**

Important assessment tool of evaluation of the heat pump are costs of the fuel. At the particular object liquefied gas is used as fuel (predominant propane). During the summer period, when power of heat pump is sufficient without operation of electric boiler, difference in costs of energy sources (electric energy – liquefied gas) reached 598 EUR or in average 150 EUR per month (Table 4). In July 2009, when energy demand was the lowest, difference in costs was only 94 EUR. During autumn period (2.25 months), when average outside air temperature was below +10 ˚C, for ensuring required energy amount for heating power of the heat pump was insufficient, therefore electric boiler was operating and difference in costs reached only 254 EUR or in average 112 EUR (Table 5). It is necessary to reduce operation of electric boiler because price of electric energy is higher than price for liquefied gas and the *COP* of electric boiler is only 0.98. Electric boiler was operating nearly 10 % of the heat pump operational time during the autumn period.

Table 3

Switching on/off operational rhythm of the compressor of the heat pump depending on set up of back-flow water

Outside air temperature, ˚C	Set up of back-flow water temperature, ˚C / at amount of heat energy for heating the panel, Wh·h^{-1}					
	36 / 60		37 / 105		38 / 120	
	Duration of the cycle, h	Operation of the compressor, %	Duration of the cycle, h	Operation of the compressor, %	Duration of the cycle, h	Operation of the compressor, %
10	Non-stop	100	3.0	85	Non-stop	100
15	1.2-1.4	35-45	3.0	85	0.25-non-stop	90-100
20	1.2-1.4	35-45	1.5	65	0.15	Variable
25	1.2-1.4	35-45	1.5	65	0.12	55

Table 4

Balance and costs of energy resources during the summer period

Period of time	Average outside air temperature of the period, ˚C	Heat energy demand for heating the resting places, kWh	Electric energy for heat energy extraction, kWh	*COP* of the heat pump	Price of liquefied gas, without VAT EUR·t^{-1}	Difference in costs of electric energy and liquefied gas, EUR
June	14.0	7241	2368	3.06	455.85	138.97
July	17.4	3922	1180	3.32	473.55	94.34
August	16.0	6816	2097	3.25	491.20	166.52
September	13.6	5850	1804	3.24	584.05	198.65
Total		23829	7449	3.20	-	**598.48**

Price of the electric energy is 0.084 EUR·kWh^{-1} (without VAT)

Table 5

Balance and costs of energy resources during the autumn period

Period of time	Average outside air temperature of the period, ˚C	Heat energy demand for heating the resting places, kWh	Electric energy for heat energy extraction, kWh		*COP* of the heat pump	Price of liquefied gas, without VAT EUR·t^{-1}	Difference in costs of electric energy and liquefied gas, EUR
			Compressor	Electric boiler			
October	5.0	7255	2753	342	2.34	498.55	110.75
November 1. decade	0.4	1988	703	502	1.61	569.80	14.72
November 2. decade	7.0	4089	1228	587	2.23	569.80	86.03
December 1. decade	3.5	2347	917	206	2.09	569.80	42.55
Total		15679	5601	1637	2.17	-	**254.05**

Price of the electric energy is 0.084 EUR·kWh^{-1} (without VAT)

Conclusions

1. Stage of the lactating-farrowing period and more substantially outside air temperature affect load of the heat pump for heat ensuring for heating resting places of piglets. During summer period the *COP* of the heat pump was within 3.25-3.30.
2. When outside air temperature declines under +10 ˚C obtained amount of heat energy decreases for about 40-50 % because of intensive frosting of evaporators. Shortage of the heat energy is covered by operating the electric boiler what turns down the total *COP* even up to 1.9-2.0.
3. It is possible to decrease frosting of the evaporators, breezing warm air with the temperature 7-9 ˚C, power of the heat pump increases for about 2.4-3.2 kW and the *COP* of the heat pump increases up to 2.40-2.45. It is usefully to organize experiments, when warm outflow air from the ventilation systems is used.

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