EFFICIENCY OF THE USE OF HEAT EXCHANGER IN THE PIGSTY

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Abstract. In the pigsty of 500 feedlot pigs were tested factory-built heat exchanger WVT-120K made by Germanys company and heat exchanger made by institute and were obtained data, what were as argument for analyze of factors, what affects on efficiency of use of heat exchangers. More essential factors are distributed heat by animals and necessary air temperature in the pigsty; minimal intensity of air interchange in winter period, what is determined by carbon dioxide quantity desorbed by animals and its' allowable concentration in the air of the pigsty; heat loss through outer building structures of the pigsty, what is determined by thermo technical parameters of drawn building materials and ambient temperature. In the paper each of these parameters is detailed analyzed and they are illustrated by results obtained during experiment in the particular object. As a result of analyze are made conclusions for choice conditions of accordant capacity heat exchangers and their influence on exploitation parameters.

Key words: heat exchanger, heat balance, age groups of pigs, ambient temperature.

Introduction

During winter period it is necessary to provide optimal indoor climate in the pigsties, what increase need for energy sources. Economical utilization of energy sources is conduces by legitimated derogation of ventilation intensity, reduction of heat loss through outer building structures of the pigsty, reduction of liquid quantity on the deck and others activities. An additional effect is attained, when in ventilation system of the pigsty heat exchanger is included. Heat exchangers well-becoming for application in the pigsties are mainly made in Germany. In order to grow in experience of utilization of heat exchangers in conditions of Latvia in the Institute of Agricultural Machinery from PVC cored-structure boards was make out and in the conditions of production tested heat exchanger [1, 2]. Heat exchanger WVT-120K made by company "Schönhammer" was acquired and tested [2, 3].

Goal of our investigation is on the basis of results obtained during an experiment to make analyzes about predictions, what conduce efficiency of use of heat exchangers in pigsties in weather conditions of Latvia.

Materials and methods

During winter periods 2006 and 2007 in experiments of heat exchangers in the pigsty Madaras-Gretes of 500 feedlot pigs in Ogre region Suntaži rural municipality obtained data in Table 1 are summarized.

Table 1

Parameters of experimental heat exchanger and exchanger WVT-120K during the testing period

Parameters	Experimental heat exchanger		Heat exchanger WVT-120K	
	in average	oscillations	in average	oscillations
Temperature in the pigsty, ˚C	16.7	13.8 – 17.6	16.0	14.7 – 16.5
Ambient temperature, ˚C	-5.1	3.3 – -16.2	-6.7	2.5 – -15.0
Fresh air grow warm for, ˚C	13.8	8.8 – 16.0	12.0	7.5 – 16.8
Regained capacity of heat flow, kW	10.5	6.5 – 12.7	11.7	4.3 – 22.4
Heat conversion ratio, W m^{-2} $°C^{-1}$	12.5	9.9 – 13.8	18.1	8.8 – 31.4
Efficiency of heat exchanger	0.63	0.55 – 0.69	0.53	0.48 – 0.65

Experiments in conditions of production have shown that parameters of application of heat exchangers are substantially influenced by heat conditions in the byre [2]. That is prescribed by successions of factors, int.al., choice regime of ventilation, heat loss through outer building structures of the pigsty, age groups of pigs and keeping conditions of them. Heat balance equation of the pigsty, what contains from one side radiant and from other side main heat loss, is following [4]:

$$Q_w + Q_p + Q_{el} + Q_{lv} + Q_b = Q_c + Q_{hw} + Q_{vap} + Q_{sp} + Q_f \ , \qquad (1)$$

where Q_w – necessary heat for heating of the pigsty, kW;

Q_p – free heat distributed by animals, kW;

Q_{el} – distributed heat by electrical appliances, kW;

Q_{lv} – distributed heat by local heaters, kW;

Q_b – distributed heat by beddings, kW;

Q_c – heat loss through outer building structures of the pigsty, kW;

Q_{hw} – heat capacity for preheating of the fresh air, kW;

Q_{vap} – heat spending for vaporization of liquid from the deck, kW;

Q_{sp} – heat capacity for heating of the infiltrate air, kW;

Q_f – heat capacity for heating from outside catered food, kW.

Evaluating calculation approximations of several elements of heat balance and their influence on common result, in the subsequent calculations are bolted Q_{el}, Q_b and Q_f. Main factors, what prescribe regime of ventilation and heating of the pigsty, are:

- desorbed heat quantity of animals and necessary temperature of air in the pigsty;
- minimal intensity of air interchange during winter, what is prescribed by carbon dioxide desorbed by animals and its permissible concentration in the air of the byre;
- heat loss through outer building structures of the pigsty, what is prescribed by heat technical parameters of drawn building material and ambient temperature.

Like data output about quantity of desorbed heat of animals, necessary quantity of air in the byre and desorbed quantity of carbon dioxide are used conventional quantity according ONTP 2-85 [5]. In particular cases for comparison are in German literature used accordant quantities [6, 7].

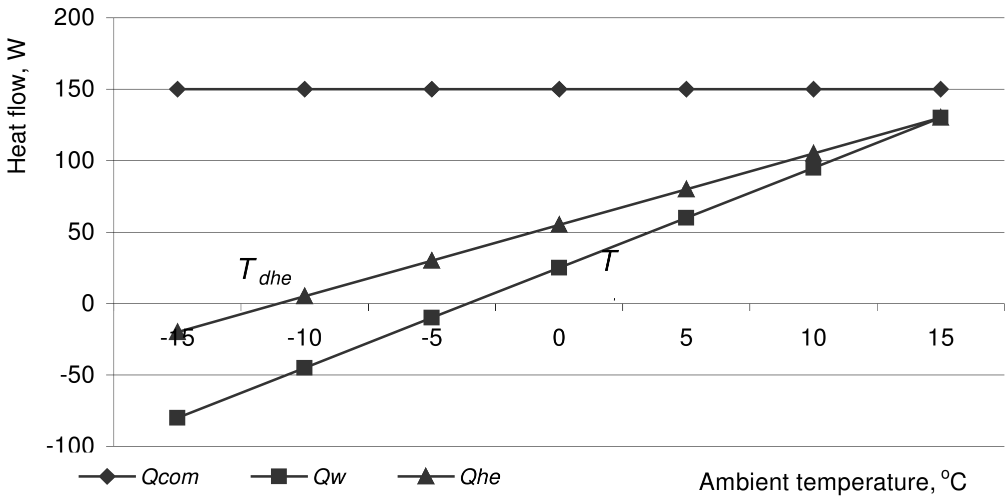

Fig. 1. **Graphically determination of temperature in which arrives heat deficit:**
Q_{com} – total capacity of radiant in the byre, W; Q_w – total heat loss, W; Q_{he} – heat loss change, when heat exchanger is used, W; T_d, T_{dhe} – temperatures in which heat deficit is arrived without and with heat exchanger, accordingly ˚C

At analyzes of heat balance of byre it is important to determine ambient temperature, in which arrive heat deficit and its amplitude when ambient temperature goes lower. Ambient temperature T_d, in which it is necessary to start preheating of fresh air, can be determined graphical (Fig. 1) or calculatedly according following equation:

$$T_d = -T_c - 2T_c \cdot Q_d \cdot \left(Q_{com} - Q_{vap}\right)^{-1}, \qquad (2)$$

where T_c – temperature in the pigsty, ˚C;

Q_{com} – total capacity heat loss, kW;

Q_d – heat deficit when ambient temperature is negative, whose numerically expression is equal to pigsty temperature, ˚C.

Results and discussion

In Table 2 are summarized accounted data about intensity of air interchange and need for heat to warm up initial air for several age groups of pigs. Thoughts are engendered by great difference of 25 – 35 % in numerical values about distributed quantity of CO_2 by feedlot pigs according ONTP 2-85 and German standards, because it substantially prepossess results of calculations about necessary intensity of air exchange and need for heat to warm up incoming air. In way of precision of minimal quantity of air exchange during winter heating period it is possible to outran tangible attenuation of consumption of energy sources.

Table 2

Intensity of air interchanges and need for heat to warm up initial air for one animal

Parameters	Age groups of pigs						
	Free sow in farrow*	Suckling sow*	Isolated piglets, 20 kg	Feedlot, 60 kg		Feedlot,100kg	
				ONTP 2-85	German data	ONTP 2-85	German data
Quantity of distributed CO_2, l h^{-1}	42	98	18	33	22	43	33
Quantity of replaceable air, m^3 h^{-1} **	15.5	36.3	6.7	12.2	8.1	15.9	12.2
Air temperature in the byre, ˚C	15	18	22	15	15	15	15
Necessary heat for warming fresh air when ambient temperature is -15 ˚C, kJ h^{-1}	630	1800	335	495	325	650	495

* with mass of sow of 150 kg;

** with maximal allowable level of CO_2 in the byre 0.3 %.

Collateral necessary quantity of heat by a long chalk is dependent on heat loss through outer building structures of the pigsty. Previously built byres predominant have 1.5 brick heavy walls. Such walls have a heat transfer coefficient of 1.6 W m^{-2} ˚C^{-1} in average.

Building standard valid at the moment LBN 002-01 for each element of building structure (wall, window, covering and others) have no strong norms of allowable heat transfer coefficient but limit common one referring it to the area of the deck [8]. Specific consumption of heat for engineering buildings is about 1.0 W m^{-2} ˚C^{-1}. That is achieved mainly in way of heat insulation of outside walls of buildings. Calculations shown that in such way recalculating heat loss for buildings with 1.5 brick heavy walls they are 1.5 W m^{-2} ˚C^{-1}.

In Table 3 are summarized results of calculations about heat loss in the byre, ambient temperature in which heat deficit is arrived and heat deficit when ambient temperature goes down to – 15 ˚C, if heat loss referable to the area of the floor through building constructions are 1.5 and 1.0 W m^{-2} ˚C^{-1}. For calculations conventional density of animals in the byre is following: free sows in farrow – 3.5 m^2, suckling sow – 7.5 m^2, isolated piglets – 0.6 m^2, feedlot pigs – 1.2 m^2. Heat losses are related to one animal.

Table 3

Heat balance in the byre, ambient temperature, in which heat deficit is entered and its quantity without heat exchanger and with heat exchanger

Parameters	Age groups of pigs						
	Free sow in farrow*	Suckling sow*	Isolated piglets, 20 kg	Feedlot, 60 kg		Feedlot,100kg	
				ONTP 2-85	German data	ONTP 2-85	German data
Free heat of pigs, W	202	430*	57**	160	140	205	197
Power of heat exchanger when $T_k - T_a = 30$ ˚C, W	90	220	30	55	45	90	70
Total heat loss ,W (-15 ˚C)							
$k = 1.5$ W m^{-2} ˚C^{-1}	412	1018	135	232	150	280	222
with heat exchanger	320	800	105	177	105	190	152
$k = 1.0$ W m^{-2} ˚C^{-1}	342	856	120	210	174	257	194
with heat exchanger	250	635	90	155	130	167	124
Heat deficit arrives at ˚C,							
$k = 1.5$ W m^{-2} ˚C^{-1}	+1	-3	-1	-4	-5	-6	-12
with heat exchanger	-2	-9	-10	-12	-12	-17	-25
$k = 1.0$ W m^{-2} ˚C^{-1}	-2	-7	-5	-7	-8	-8	-16
with heat exchanger	-9	-16	-18	-16	-19	-24	-35
Initial change of heat deficit, ˚C							
heat insulation of byre	3	4	4	3	3	2	4
with heat exchanger, if							
$k = 1.5$ W m^{-2} ˚C^{-1}	3	6	9	8	7	11	13
$k = 1.0$ W m^{-2} ˚C^{-1}	7	9	13	9	11	16	19
Heat deficit, W (–15 ˚C)							
$k = 1.5$ W m^{-2} ˚C^{-1}	205	345	38	72	53	75	25
with heat exchanger	115	125	9	18	10	+12	+45
$k = 1.0$ W m^{-2} ˚C^{-1}	135	180	23	50	32	52	+3
with heat exchanger	45	+20	+5	+5	+25	+40	+73

* in the liaison of suckling sows is additional warming-pan with power of 250 W;

** in the liaison of isolated pigs is additional warming-pan with power of 25 W/piglet;

*** heat loss with or without use of heat exchanger are referred to one animal.

Data summarized in Table 3 gives, that, when ambient temperature goes down, in most cases byre has to be warmth at temperature from -3 - 8 ˚C. Reduction of heat loss in the newly erected objects according to request of the LBN 002-01 or heat insulation of existing buildings change initial temperature of heating from 2 to 4 ˚C. Operation temperature of heat exchanger, in which it is needed to start heating of byre, in most cases is changed from 7 to 15 ˚C, wherewith necessary heat economy for warming of byre is given.

Necessary quantity of hear for warming of byre and its economy, in case of using heat exchanger, is calculable according to measurements of ambient temperature in February 2006 of experimentation of experimental heat exchanger in the pigsty of 500 feedlot pigs in Suntaži rural municipality. Ambient temperature and frequency of temperature in Fig. 2 are shown. Have to be noted that February of 2006 was relative cold and average temperature in February was -6.1 ˚C. Perennially observed average air temperature in Riga in January is -4.9 ˚C, in February -4.6 ˚C.

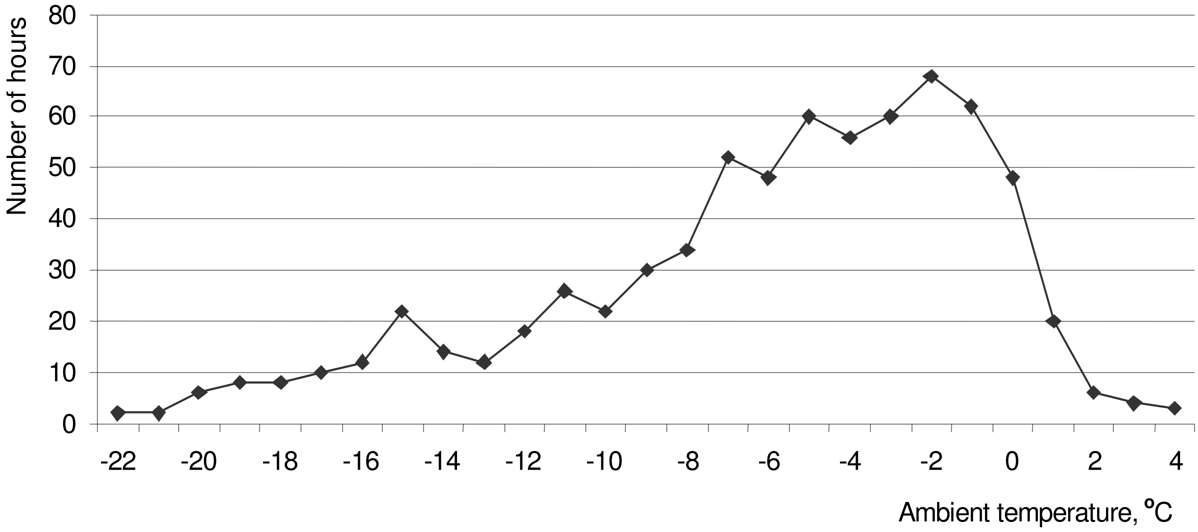

Fig. 2. **Number of hours with accordant ambient temperature during period of 30 days in period of time from February 1 to March 3, 2006**

In Table 4 there are given results of calculations about energy consumption to cover heat deficit in the pigsty of 500 feedlot pigs according to the ambient temperature in the February 2006. Results of calculations shows that utilization of heat exchanger in particular conditions can reduce at least 85 % of energy consumption for warming byre. Whereas heating of byre reduce specific heat loss through delaminating building constructions about one third, need for energy sources for warming byre in specific conditions decrease in two.

Table 4

Utilization of energy for defray of deficit in pigsty of 500 feedlot pigs accordant actual ambient temperature in February 2006

Parameters	**Mass of piglets 60 kg**		**Mass of pigs 100 kg**	
	$k = 1.5$ W m^{-2} °C^{-1}	$k = 1.0$ W m^{-2} °C^{-1}	$k = 1.5$ W m^{-2} °C^{-1}	$k = 1.0$ W m^{-2} °C^{-1}
Regained quantity of heat with heat exchanger during one month, MJ	54		81	
Additional need for heat, MJ: without heat exchanger with heat exchanger	 31.5 4.8	 14.6 1.4	 24.4 0.6	 12.8 -
Economy of heat energy: with heat exchanger, MJ % only with heat insulation, MJ %	 26.7 84.8 	 13.2 90.4 16.9 50.6	 23.8 97.5 	 12.8 100.0 11.6 46.2
Efficiency of exploitation of heat exchanger, to cover heat deficit (accordant to calculatedly intensity of aeration to CO_2), %	49.4	24.4	29.4	15.8

Calculations given in Table 4 shows that even in period of comparatively colt weather effectively are used not more than one half from total regained quantity of heat with heat exchanger.

However regard that exploitation of heat exchanger either at cold ambient temperature gives positive effect and provides optimal relative humidity in byre at the smallest interchange of air.

Conclusions

1. Specific heat loss has diminished when it is provided maximal optimal density of animals in period of cold.
2. Particularization of recommendations about desorbed quantity of CO_2 by animals and determination of accordant to that minimal interchange of air would give chance substantially decrease consumption of energy for warming of fresh air.
3. Previously built byres, for example, with 1.5 brick heavy walls, have comparative big volume of heat loss that decreases efficiency of exploitation of heat exchanger. Such byres have not to conform to requests of new build normative LBN 002-01. It is recommended making heat insulation of building. If the byre is heat insulated temperature in which heat deficit is began decreases for 3-4 ˚C.
4. Exploitation of heat exchanger changes temperature in which began heat deficit in average in two times more than in performance of insulation. Need for energy sources for heating of byre during moth of experiment has decreased for 90 %.
5. Efficiency of exploitation of heat exchangers increases when its operation regime is trusted by common control system of microclimate.

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