Katarzyna SZWEDZIAK, Robert SZULC, Żaneta PRUSKA
Politechnika Opolska, Katedra Inżynierii Biosystemów
ul. Mikołajczyka 5, 45-271 Opole, Poland
e-mail: k.szwedziak@po.opole.pl; z.pruska@po.opole.pl

PROJECT ASSUMPTIONS AND RESEARCH METHODOLOGY OF AUXILIARY ENERGY EFFICIENT HEATING SYSTEM FOR PIGLETS WITH HEAT RECOVERED FROM OVER THE FARROWING SOWS

Summary

This paper features project assumptions, the description of the patented in ITP research station for the innovative cooling and heating system in pens for farrowing sows and piglets and the research methodology. Field tests aim at specifying energy efficiency and economy of the tested system and the impact of the heat recovery installation in the pen on animals' behaviour, health, body weight gain. Measurements in the first stage of research concern specifying the amount of the recovered heat from over the farrowing sows and the efficiency of its reuse for heating piglets after processing the temperatures at various points of the installation in the heat pump.
***Key words**: heat, pig house, renewable energy, heating piglets, welfare*

ZAŁOŻENIA PROJEKTU ORAZ METODOLOGIA BADAŃ NAD EFEKTYWNOŚCIĄ POMOCNICZEGO SYSTEMU OGRZEWANIA PROSIĄT Z CIEPŁA ODZYSKANEGO Z MACIOR

Streszczenie

Artykuł przedstawia założenia projektu, opatentowanego w stacji badawczej ITP dla innowacyjnego system chłodzenia i ogrzewania w kojcach porodowych dla macior i prosiąt, oraz metodologii badawczej. Badania terenowe mają na celu określenie wydajności energetycznej badanego układu oraz wpływu instalacji odzysku ciepła w zagrodzie na zachowania zwierząt, zdrowie, przyrosty masy ciała. Pomiary na pierwszym etapie badań dotyczą określenia ilości odzyskiwanego ciepła sponad macior oraz efektywności ponownego wykorzystania ciepła dla prosiąt po jego przetworzeniu w różnych punktach instalacji w pompie grzewczej.
***Słowa kluczowe**: ciepło, chlewnia, energia odnawialna, ogrzewane prosięta, dobrostan*

1. Introduction and justification for the selection of the subject matter

Present interest in application of renewable energy sources, including in agriculture, stems from the increasing price of energy produced with traditional methods increasing environmental pollution from emissions of gasses, odours and dusts. The use of Renewable Energy Resources gradually increases in the framework of the Polish agriculture energy demand. In 1996 it amounted to 14%, and in 2002 – 15%. Forecasts [8] quoted the use of RES in agriculture at the level of 21% by 2010. This trend faces increasing popularity in Poland, in particular in agriculture, especially that Poland experiences increasing energy demand [12]. In agriculture, mainly in animal production, modern equipment is advised together with methods allowing for the control, analysis and the development of technology tasks such as, among others: feeding, removing manure, milking, heating animals, ventilation with simultaneously assuring animal welfare and striving for implementation of energy saving systems, including heat pumps [4, 7]. Adequate microclimate in the inventory building, constituting one of the main factors fostering successful breeding of livestock, is decisive for their proper development, rapid growth and good health. Its main parameters are: air temperature, humidity, composition and movement. Creating and maintaining adequate microclimate in inventory rooms is crucial. Assuring adequate temperature in pig houses, especially in farrowing pens, is not an easy task. Piglets are very sensitive to temperature shocks and to inadequate temperature. Conditions required in swine farrowing pens are very specific with maintaining air temperature at a different level for the sow (lower temperature) and for piglets (higher temperature) [11]. The research [9] resulted in conclusions that the best temperature for farrowing sows is between 18-20^{o}C (Table 1). Increase in temperature may lead to the sow's temperature discomfort triggering her nervous behaviour and increased movement activity leading to crushing the piglets. Too much heat in the pen results in decrease in appetite of animals and it is the reason for distortions in the process of producing milk and may lead to aggressive behaviour. On the other hand, if the temperature is too low, it causes colds and increased feed intake [1, 2, 3]. Newborn piglets' body temperature is around 40^{o}C, and their thermoregulatory system is poorly developed – they do not have a fat layer protecting them against cold. Reducing their body temperature to 35^{o}C or lower may lead to their death. Consequently the ambient temperature of newborn piglets should be around 32-34^{o}C (Table 1).

Consequently, artificial heating for piglets is very important. In additionally heated piglet nests equipped in additional roofs maintaining the required temperature for piglets, heating equipment hanged above piglets, floor heating systems or gas heating systems are used. The latter one is very rare due to the fact that numerous farms do not have gas installation and the burning gas produces exhaust emissions and poses a risk of fire and requires additional oxygen supply. The most widespread method using power available

everywhere consists in hanging heating elements such as: infra-red lamps. They are easiest in servicing, but also the least durable, unfortunately. The exploitation cost due to relatively low purchase price is reduced only to the cost resulting from power consumption that is the power of the applied heating elements and the time of operation. The frequency at which bulbs have to be replaced influences the costs, and it depends on the care in managing infra-red lamps. One drawback of this type of infra-red lamps is large energy loss, due to very small, most beneficial for piglets, surface of the heated area in respect to the bulb. The computer visualisation of temperature distribution in the piglets' nest presented in figure 1 confirms the statement. Consequently, it would be better to construct heating solutions to make the temperature distribution more even and proportional to the power of the heating equipment. Surface-floor heating elements, suspended or wall elements may constitute such a solution.

To respond to the problems connected to the need of reducing energy consumption (and for economic reasons) in animal production and the increasing use of Renewable Energy Resources resulting from among others Poland's international obligations of UE Directives up to 2020, the prototype of an innovative heating-cooling system for animals in pig houses has been designed, constructed and tested at the Institute of Technology and Life Sciences (Department in Poznań).

2. Research task

Based on the detailed analysis of the available knowledge and own tests, the following research task has been diagnosed in the form of the following questions:

1) What energy and economic efficiency has the innovative heating-cooling system for sows and piglets in the pig house?
2) What is the impact of the heating-cooling installation located in pens on the behaviour and animal welfare?

3. Research Goal and Scope

The main goal of the undertaken research is to verify in real conditions the technical efficiency of the piglets heating system with the heat recovered from cooling the farrowing sows and to conduct energy and economic analysis of the exploitation of this system in reference to the existing traditional technical solutions.

Table 1. Air temperature, humidity and movement values in swine rooms [9]
Tab. 1. Wartości temperatury, wilgotności i przepływu powietrza w zagrodach dla świń [9]

Swine age group	Temperature [°C]		Relative humidity [%]	Air movement speed [m·s^{-1}]	
	Maintenance system				
	Straw	Grating		Summer	Winter
Piglets 1-4 days old	24-30	30-34	60-70	0.2	0.15
Piglets 5-14 days old	26-28	28-31	60-70	0.2	0.15
Piglets around 14 days old	22-25	24-28	60-70	0.2	0.15
Older piglets	16-24	22-26	50-60	0.3	0.2
Farrowing sows	15-18	18-22	60-70	0.4	0.2
Pigs for fattening	12-18	18-20	60-70	0.4	0.2
Pigs for fattening around 100 kg	14-16	18-22	60-70	0.4	0.2
Boars	15-18	15-18	60-70	0.5	0.3

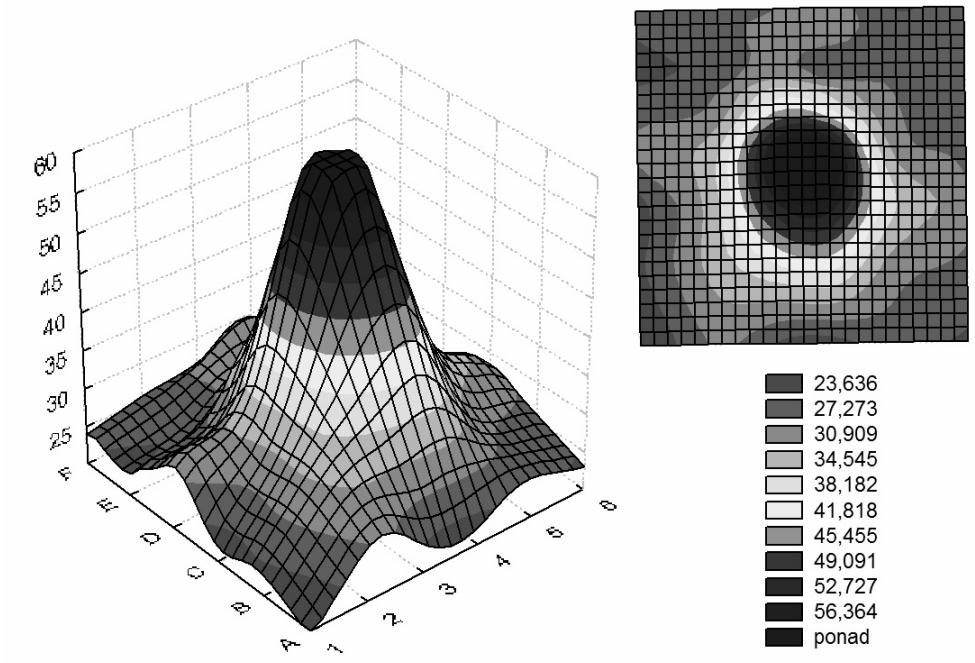

Fig. 1. Temperature distribution on the floor (°C) in piglets' nest with the use of the traditional infra-red lamp [11]
Rys. 1. Rozkład temperatury na posadzce (°C) w gnieździe prosiąt przy zastosowaniu tradycyjnego promiennika lampowego podczerwieni [11]

Another goal is to verify the health state of the cooled sows, their level of aggression, lactation, behaviour in the pen and the relationship with piglets as a reaction to additional tested equipment located in the pen.

Additional goal is to realise a detailed analysis of the development of the heated piglets – their daily body gain, mutual relationships and standard behaviour in the pen with farrowing sow in the presence of the tested installation with its new construction.

4. Research station

Research station has been designed, constructed and realised based on the patent application no P-404762 ["Urządzenie dogrzewająco-chłodzące kojce dla loch i prosiąt" ("Pens' heating-cooling equipment for sows and piglets")]. The research station (Fig. 2) consisted of four pens for sows and piglets. Two of the pens are equipped with the innovative heat management system (heat procured from the cooled sow and simultaneous heating of the modified piglets' nest) and the two remaining constitute the control group with traditional heating equipment. The pens' heating-cooling system is made of two cooling modules *1* (coolers) suspended above the sows' bed, *10* combined parallel with the installation *2*operated by technical glycol and connected in a closed circuit with the heat pump *3*. The heat pump, through a long closed circuit *4* heats up the central heating water in the buffer *5*. The water buffer is a container where ready to use hot water is collected. It is ready to heat the piglets' nests – *9*. With the third closed circuit *6* the hot water reaches particular piglets' nests *7* equipped with wall and floor heat exchangers – heaters *8*. The installation is operated by electric power source which is the traditional electric power source in the inventory building providing power to the heat pump and two export pumps (glycol and hot water).

The installation operates in the following manner: In the first stage of operation, in the first closed circuit, the heat pump collects heat from air in the inventory room directly over the sows. Glycol circulating between the cooler and the heat pump collects the heat from the air and transfers it to the heat pump. The heat pump in the second circuit delivers hot water to the buffer container which is the container of the central heating water. The hot water is parallel distributed from the container through a third closed circuit to particular piglets' nests and there, through heat exchangers – floor and wall panels the heat is provided to heat the piglets and the cool water returns to the buffer.

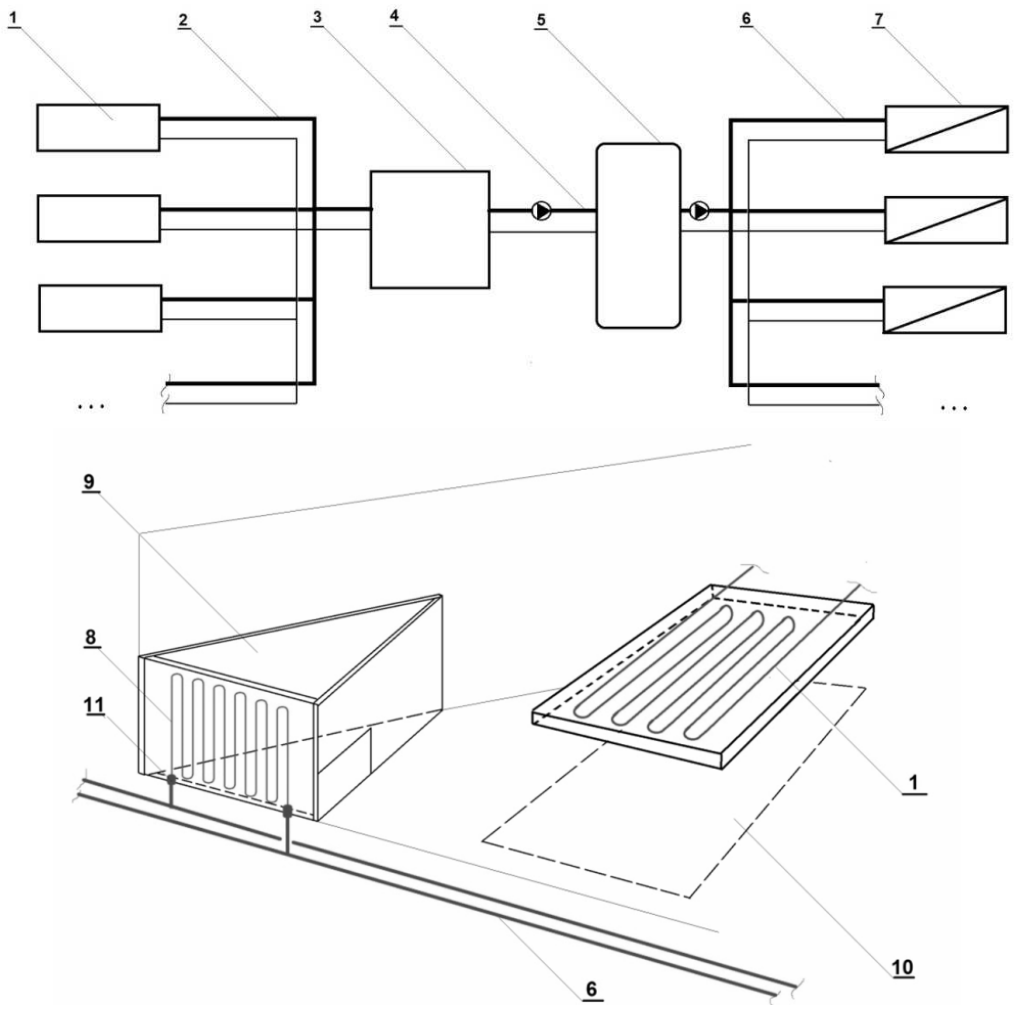

Fig. 2. Chart of an innovative pen for farrowing sows and piglets in the ITP Renewable Energy Workshop. Department in Poznań [10]

Rys. 2. Schemat innowacyjnej zagrody dla macior i prosiąt w Pracowni Energii Odnawialnej ITP, Oddział w Poznaniu [10]

5. Research methodology

The research station composed of four pens for farrowing sows and for piglets, the installation of the cooling-heating system, the control-measurement equipment of the heat pump, the installation for heat transportation are located in the Renewable Energy Workshop building (Fig. 3) "Ekobudynek" (Ecobuilding). During the conducted analysis the heat energy efficiency indicator COP (Coefficient Of Performance) has been specified. It shows the energy efficiency of the system in use. This indicator has been produced as the quotient of the acquired energy and the incurred energy supply. Energy supplies resulting from the work of the installation for heating piglets' pens acquiring heat from the air from over farrowing sows have been specified based on the use of active power energy (calculated in kWh) by the heat pump and circulating pumps in a specific time.

Source: own work / Źródło: opracowanie własne

Fig. 3. Part of the Renewable Energy Workshop with pens subject to tests and the installation and the heat pump in the background

Rys. 3. Część Pracowni Energii Odnawialnej z zagrodami poddanymi próbom oraz instalacja i pompa ciepła na dalszym planie

Moreover, the measurement of external air temperature and the heated room were taken simultaneously. Measurements were realised daily at the same time of the day. Temperature inside the pen (at the height of 0.5 m over the floor) was taken in four selected locations of the inventory building and heat meters were read, located on the installation delivering heat from the panel cooling sows to the heat pump and the heat stream going to piglets' nests. The applied heat meters allowed for taking measurements such as:

- the amount of heat transferred from over sows to the heat pump Q_L, GJ,
- the amount of heat transferred from the heat pump to the buffer container Q_{PC}, GJ,
- the amount of heat transferred to piglets' nests from the buffer container Q_{PR}, GJ,
- temperature of the heating medium directed to the heating pump from the stations with sows T_L, °C,
- temperature of the heating medium directed from the buffer container to the piglets' nests T_L, °C,
- temporary power of systems P, kW,
- the size of the flowing stream of the working medium [$m^3 \cdot h^{-1}$],
- the amount of the acquired energy [kWh].

The Renewable Energy workshop is made of a self-supporting construction building without internal partition walls, with the following external dimensions: 12 m x 6 m, and the walls are made of steel sheet filled with 10 cm of Styrofoam. "Ecobuilding" is equipped with a liquid solar collector as a roof, its surface amounts to about 83 m^2.

The reading of the control-measurement equipment is not possible with the use of a portable computer, therefore all necessary collected on an ongoing basis measurements data are read and noted down by hand by the employee, and entered in the computer with the use of the Excel software, they are subject to processing and analysis and preparation for publication.

Energy supplies resulting from the work of the presented installation acquiring heat from the stations with sows and heating piglets have been specified based on the use of the active energy (calculated in kWh) by the heat pump and circulation pump in a specific time in the installation. Electric meter of active power has been installed at the research station in the "Ecobuilding" and combined with the whole installation. The circuit pump's use of electricity has been specified based on the working time (assumed 24 h per day) multiplied with the equipment's power (80 W).

The innovative system of heat recovery and re-use has been subject to comparative studies aiming at showing differences in energy inputs and in the further stage – economic, of the patented cooling-heating system and the traditional system with the use of classical infra-red lamps of 170W of power, installed in every piglets' nest.

The conducted analysis of literature and the initial research allowed for forming criteria of evaluation and to realise the energy-economic analysis of the tested solution. The criterion comprises heat transforming installation exploitation costs: heat pump, circuit pumps, heat meters, buffer container, safety valves.

A – unitary costs connected to heating piglets' nests with traditional method,
B – unitary costs connected to the exploitation of the heat acquiring system,
C – temperature in the pen for sows and piglets without the heat recovery system in summertime,
D – temperature in the pen with the heat recovery system in summertime.

$$\{A > B\} \rightarrow min. \qquad \{C > D\} \rightarrow min. \qquad (1)$$

having the role of the function of the goal.

Inputs connected to the exploitation of the heat acquiring system covered the following:

- energy inputs connected to the heat pump exploitation, kWh,
- energy inputs connected to the circuit pumps exploitation, kWh,
- the cost of potential repair and ongoing repair.

Stage 3. Evaluation of the solution

The final evaluation of the tested installation has been conducted based on the verification of satisfying condition

included in the formula (1). Basic criteria taking this condition into account were as follows:
(A) - Unitary power use during heating the piglets, [kWh·day^{-1}],
(B) - Unitary cost of maintenance, use and exploitation of pens with sows and piglets, [PLN·day^{-1}].

6. Discussion and analysis of results

Practical application of the achieved results of the conducted exploitation research of the cooling-heating system for sows and piglets will entail the possibility to reduce energy input and consequently, the economic input in pig houses. Another stage involves the preparation for commercial implementation of the tested systems in agricultural holdings and in private households. Further research of animal behaviour in pens equipped with additional innovative installations will provide response to the question of the impact of the presented system on farrowing sows and piglets, and this issue is extremely important among others due to animal health, daily weight gain and feed absorption and resistance to stress.

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