Optimization of technological processes in animal husbandry

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Abstract. The article is devoted to the topical problem of rational use of energy and nutrient content of feed in obtaining livestock products (milk) from cows by shifting the energy balance of the animal's body towards "productive energy", i.e. the synthesis of fat and proteins. The authors would like to point out that one of the main factors influencing fluctuations in the energy balance of an animal are microclimate parameters, as the deviation of the microclimate parameters from the established optimal limits leads to a reduction in milk yields by 10 to 20%. Therefore, the aim of our work is to develop an energy-saving technology for the formation of optimal microclimate in livestock facilities using air conditioning systems, which can regulate most of the parameters of the microclimate inside them, namely: temperature, relative humidity and internal air velocity, concentration of harmful gases (carbon dioxide, ammonia, and hydrogen sulfide), dust and microorganisms. The presence of the mode enabling recirculation air purification allows to save heat energy and energy coming with feed by up to 50% compared with typical microclimate systems. To this end, we have systematized separate data from scientific researches done by various scientists in the fields of animal hygiene and veterinary medicine and obtained dependencies of influence of microclimate parameters (temperature, relative humidity, internal air velocity) on the productivity of animals (cows) and feed consumption.

1 Introduction

Full feeding refers to feeding where rations fully meet the needs of animals not only in energy or calories (general nutrition) determined by feed standards, but also in the necessary quantity and proper ratio of various nutrients and biologically active substances (protein, carbohydrates, fats, macro- and micronutrients and vitamins) [5, 7].

The nutritional value of the feed cannot be expressed by a single indicator. The nutritional assessment of the feed is made up of the following [4, 7, 12]:
1) its chemical composition and calorie content;
2) nutrient digestibility;
3) general (energy) nutrition;
4) protein, mineral and vitamin nutrition value.

Manufacturing of animal products such as meat, milk, eggs, wool, herd reproduction, as well as the use of livestock in agricultural work are associated with the use of energy and its transformation [5, 6]. The main elements of the energy exchange balance are shown on figure 1.

The amount of metabolic energy yielding products other than the body's heat production is also reduced by so-called non-productive energy needs: the energy needs of the animal, consisting of thermoregulation, which is necessary to maintain constant body temperature, and the energy expended on movement [4, 6, 12, 14, 19].

Insufficient energy feeding of animals causes a decrease in dairy, meat and egg productivity and exhaustion of animals, and in their young it can slow down or stop growth, cause a decrease in fertility, ovulation in the uterus and fertilization [4, 6, 7, 14, 19].

Therefore, the main goal of our work is to shift energy exchange towards productive energy with new technologies and technical means.

2 Background

2.1 Development of energy-saving technology for formation of optimal microclimate in livestock facilities

The developed technology can affect most parameters of the microclimate and maintain within the specified limits temperature and relative humidity of air, air velocity, concentration of harmful gases (ammonia, carbon dioxide, and hydrogen sulfide), dust and microorganisms [3, 4, 6, 7, 8, 10, 12, 14, 15, 19]. The technological process of a microclimate system with air conditioning includes such operations as heating, cooling, humidification, drying and purification of air from

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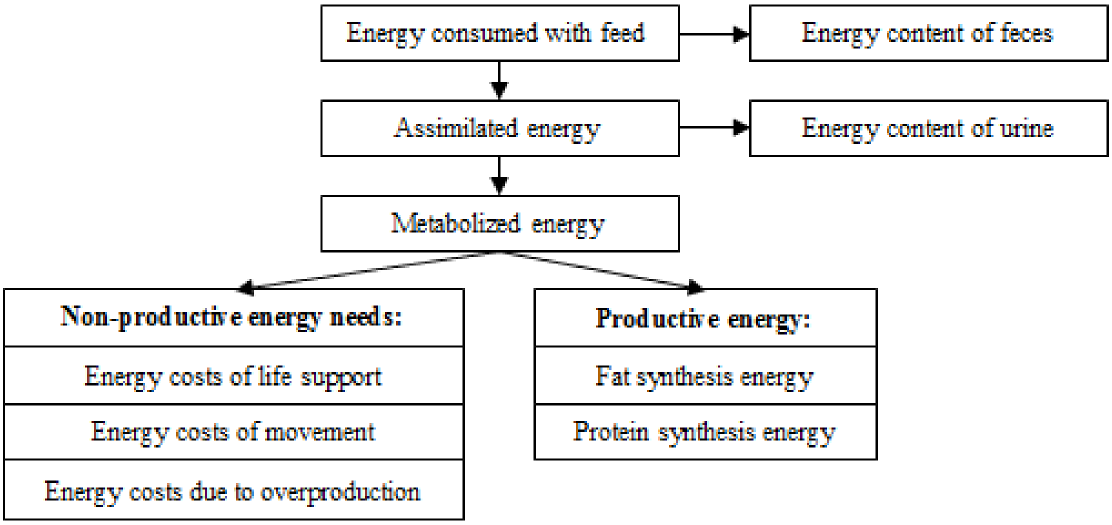

Fig. 1. Highlights of the energy exchange of farm animals.

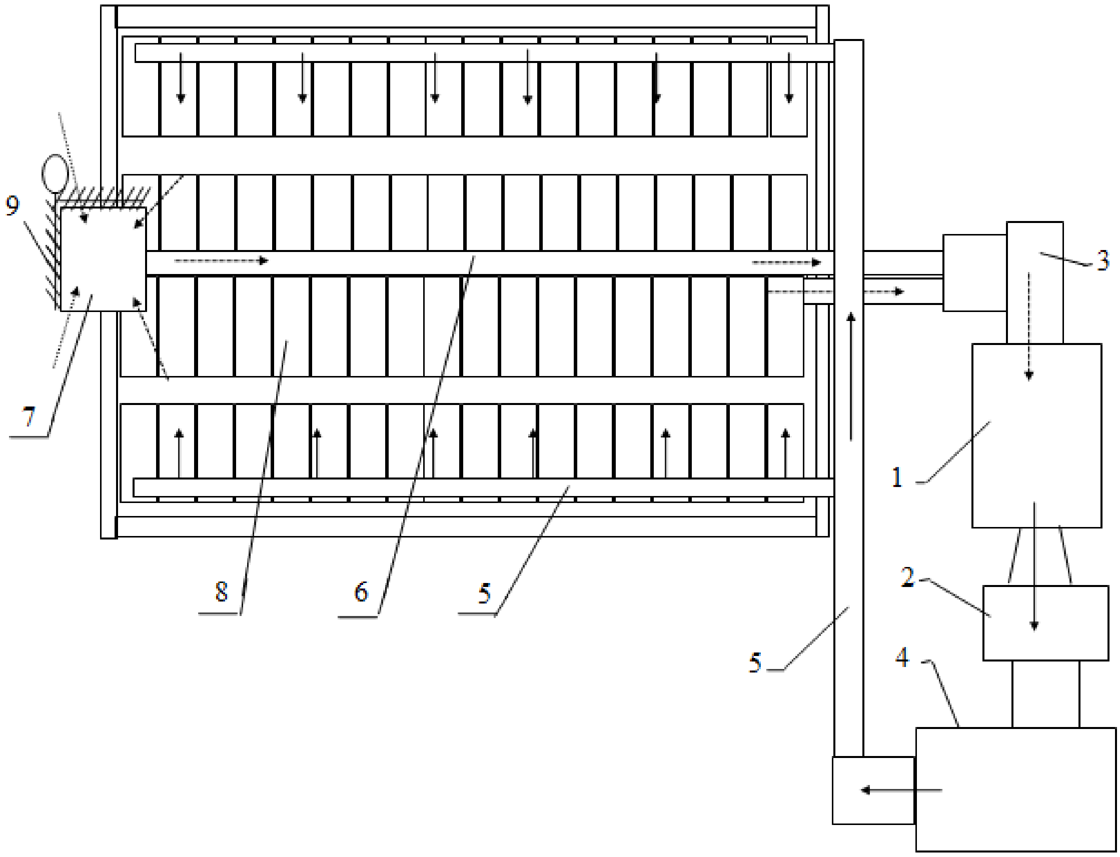

Fig. 2. Energy-saving technology for the formation of the optimal microclimate in livestock facilities with air conditioning (1 – aero-hydrodynamic air conditioning unit bubble chamber; 2 – electric heater; 3 – fan; 4 – fan; 5 – air distribution system; 6 – air dryer; 7 – air dryer mixing chamber; 8 – pens with animals; 9 – louvre valve with actuator; ⟶ Outside air; - - - -▸ Recirculated air; ········▸ Clean air).

harmful gases, dust and microorganisms. The operations are carried out as follows (Figure 2).

Electric heater 2 carries out air heating. The air is hydrated and cooled in the air conditioner chamber 1; drying is done by the electric heater 2 and air dryer 6. During the summer, water-evaporative air-cooling is used in the air conditioner chamber 1.

To clean the internal air from moisture, an air dryer with a mixing chamber 7 is used, into which the outside and inside air is sucked in. The automatic mode of operation of the mixing chamber eliminates icing during the winter. Then this mixture moves along the air dryer 6 and is additionally heated by the air in the upper zone of the room (in this case, moisture condenses on the outer surface of the air dryer and drains onto the lower Vshaped apron and is drained into the sewer). The fan of air conditioner 3 feeds the main flow of contaminated air into the chamber, where it is moisturized and cleaned from ammonia, carbon dioxide, hydrogen sulfide, dust and microorganisms, and then treated with the electric air heater 2. Air is supplied to the room through an air distribution system 5. The polluted air is removed from the upper zone of the room using natural ventilation shafts.

Preliminary studies have demonstrated that in real modes of operation of livestock facilities, the temperature and humidity of the indoor area are unevenly distributed and thus we can single out two zones: the upper one – the area of service personnel and the exchange ventilation and the lower zone containing animal pens.

Temperature, moisture content, CO2 and NH3 contents in pens for the stationary mode are determined on the basis of balance equations for heat and mass.

2.2 Optimization of the technological regimes of the microclimate system of livestock facilities

Existing microclimate systems on farms in their physical buildup do not have air purification and recuperation devices [1, 5, 11, 13, 16, 17, 18, 20, 23].

One of the main solutions to this problem is the optimization of the microclimate on farms based on energy-saving systems with devices performing chemical treatment of contaminated air from water vapors, ammonia, carbon dioxide, hydrogen sulfide, dust and harmful microorganisms. Formation of a regulatory microclimate on farms requires a large amount of energy; the energy costs of maintaining the microclimate are approaching the costs of feeding the animals [2, 5, 9].

Therefore, research related to the development of energy-saving systems for ensuring regulatory microclimate in livestock facilities, especially at present as the costs of energy resources are high, is relevant, and the solution to this problem is associated with a great economic effect [21, 22].

That is why our next goal was to optimize the parameters of the microclimate of the livestock facility, that will require the least amount of energy to create and maintain while achieving the greatest productivity of animals.

For this, we propose a project to optimize the parameters of the microclimate, which for clarity is presented in graphical form in the figures 3 and 4.

I quadrant presents the dependence of animal productivity (milk yield) on different parameters of the microclimate of the livestock facility. Parabolic dependence (see figure 3) is observed for such microclimate parameters as temperature and relative humidity, air velocity inside the livestock premises. An arch (see figure 4) depicts the contents of harmful gases in the air (carbon dioxide in particular).

Mathematical dependence of animal productivity (milk yield of cows) on the various parameters of the farm microclimate is presented in Table 1.

II quadrant is the section of the coordinate system that reflects the value of output per unit of time (hour, day, and year).

III quadrant displays energy requirements for creating and maintaining a given microclimate parameter value.

IV quadrant is the section of the coordinate system that shows the cost of the energy used.

After the formation of all four sectors of the coordinate system, it is possible to determine—by setting the value of the microclimate parameter (point A) and moving along the arrows—energy costs, production efficiency.

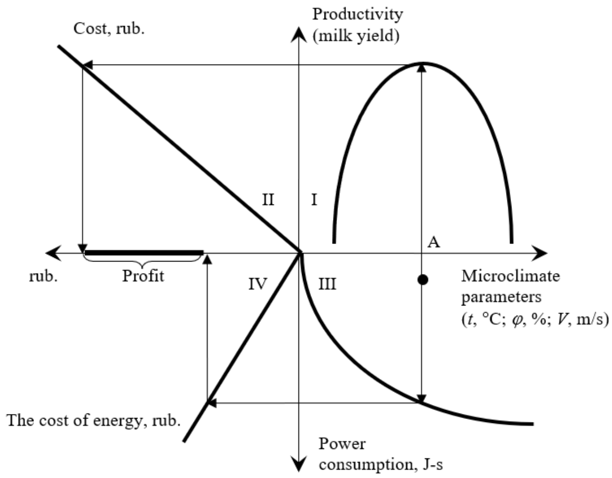

Fig. 3. Optimization of the parameters of the microclimate inside livestock facilities.

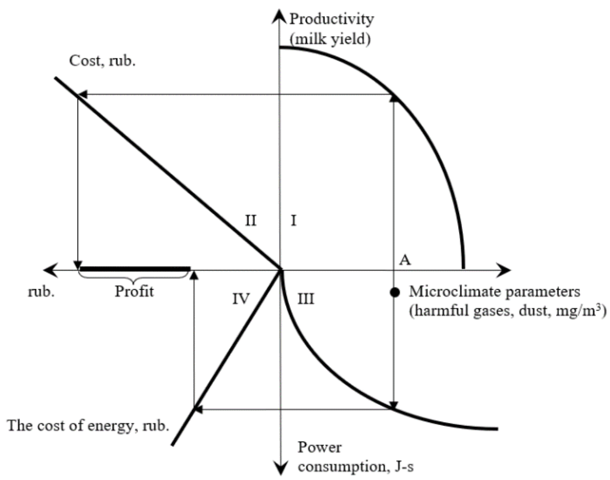

Fig. 4. Optimization of the parameters of the microclimate inside livestock facilities.

To achieve this goal, the authors summarized and established patterns of influence of the above factors on animals, developed low-energy methods and ways to eliminate negative actions, found positive technological influences of factors on productivity, product quality and ethology (behavior) of animals.

Table 1. The impact of microclimate parameters on cow productivity and feed consumption [4, 5, 6, 7, 9, 10, 12, 14, 19].

Type of animals, indicator	The regression equation	Limits
1	2	3
Cow		
Taking into account the ambient temperature, t_B, °C:		
milk yield, *Kм*, %	$K_м = -0{,}00013 \cdot (t_B)^4 + 0{,}0052 \cdot (t_B)^3 - 0{,}0637 \cdot (t_B)^2 + 0{,}3118 \cdot (t_B) + 97{,}651$	$-20 \le t_B \le +40$
milk yield of a highly productive cow, *Kм*, %	$K_м = 2 \cdot 10^{-15} \cdot (t_B)^3 - 0{,}2 \cdot (t_B)^2 + 5 \cdot (t_B) + 70$	$-5 \le t_B \le +30$
feed consumption, *Kк*, %	$K_к = 0{,}0084 \cdot (t_B)^2 - 1{,}7472 \cdot (t_B) + 131{,}45$	$-30 \le t_B \le +40$
Taking into account the air velocity *V* in terms of temperature t_B, °C:		
milk yield considering air velocity, *Kм*, %	$K_м = -0{,}00011 \cdot (t_B)^4 + 0{,}0074 \cdot (t_B)^3 - 0{,}1684 \cdot (t_B)^2 + 1{,}5186 \cdot (t_B) + 94{,}131$	$-20 \le t_B \le +50$ during winter – V_B = 0,3…0,4 м/с during summer – V_B = 0,8…1,0 м/с
milk yield of a highly productive cow considering air velosity, *Kм*, %	$K_м = -0{,}2 \cdot (t_B)^2 + 7 \cdot (t_B) + 40$	$-5 \le t_B \le +35$
Taking into account the relative humidity of the ambient air, φ_B, %:		
milk yield, *Kм*, %	$K_м = -6{,}6 \cdot 10^{-4} \cdot (\varphi_B)^3 + 0{,}1207 \cdot (\varphi_B)^2 - 7{,}224 \cdot (\varphi_B) + 242{,}22$	$50 \le \varphi_B \le 100$
feed consumption, Kк, %	$K_к = 0{,}01548 \cdot (\varphi_B)^2 + 1{,}9542 \cdot (\varphi_B) + 160{,}37$	$50 \le \varphi_B \le 100$
Taking into account the concentration of carbon dioxide in the indoor air, μ_{44} (CO_2), %:		
milk yield, *Kм*, %	$K_м = 1{,}9268 \cdot (\mu_{44})^2 - 27{,}4072 \cdot (\mu_{44}) + 97{,}3947$	$0 \le \mu_{44} \le 6$

3 Conclusions

1. According to scientists, livestock specialists, and technologists, animal productivity is determined by: 50...60% – feeds, 15...20% – care, 10...30% – microclimate in the livestock premises.

2. By studying the energy-saving methods of microclimate formation, we have compiled dispersed data from various scientists in the field of animal hygiene and veterinary medicine and have obtained dependence of the influence of microclimate parameters (temperature, relative humidity and internal air velocity, concentration of harmful gases (carbon dioxide) on animal productivity (milk yield of cows) and feed consumption.

3. When designing and developing microclimate systems, more parameters of the microclimate should be taken into account than required by the typical method (temperature and relative humidity of air, concentration of carbon dioxide).

4. Modern typical microclimate systems have the following drawbacks:
• they do not provide regulatory microclimate on farms, as they regulate mainly temperature and air modes;
• their work is based on the multiplicity of air exchange in the premises of 3...5 times/h, so the efficiency of using the heat of the internal air during the winter period of the year does not exceed 25...30%;
• there is no air recycling regime (according to domestic and foreign scientists, it allows to save up to 50% of heating costs compared to other ventilation systems);
• they cannot be operated during the summertime, as they do not provide temperature reduction inside the farm.

5. Lack of methodology and principles for building energy-saving heating and ventilation systems in livestock production prevents the development of practical methods for the development and engineering calculation of energy-saving air conditioning systems in livestock facilities.

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