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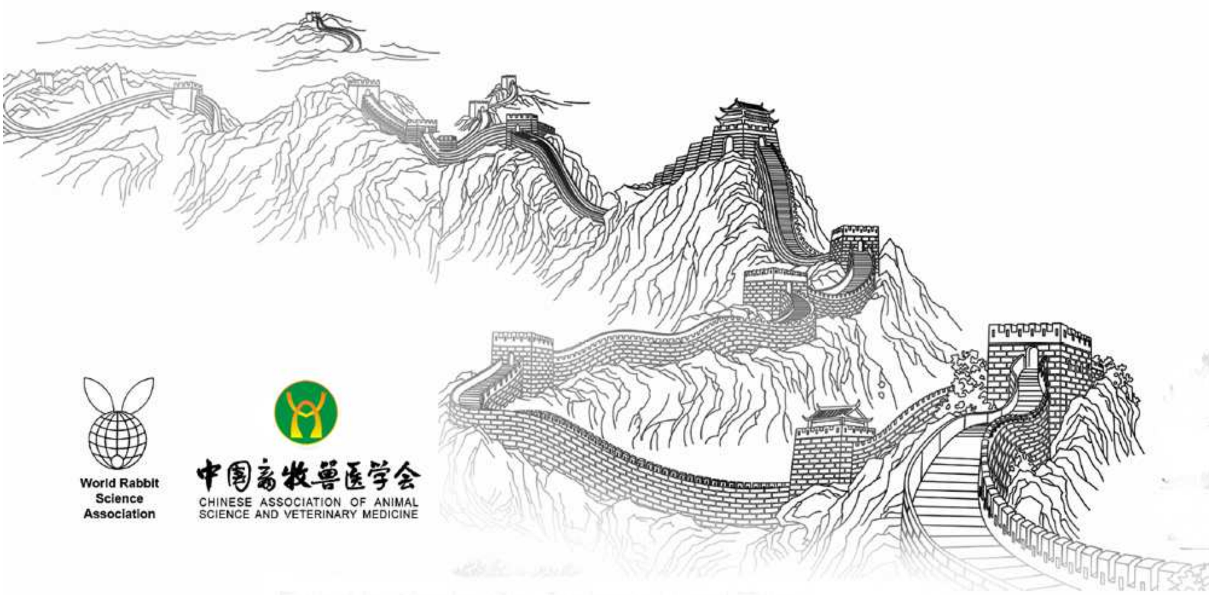

ENERGY BALANCE AND ATMOSPHERE MANAGEMENT PARAMETERS OF BUILDINGS FOR RABBITS

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ABSTRACT

This study analyzed the various energy expenses in a rabbit building. It also optimized air flow and building design through an original approach to ventilation study based on the development of a computer model. The challenge is to optimize energy consumption in existing facilities and offer to new investors effective solutions to make the rabbit activity more competitive.

Key words: energy expenses, heat losses, air flow, ventilation, heating position, cooling position.

INTRODUCTION

In an economic context of permanently high prices for energy and increasingly competitive meat market, farmers have to improve their competitiveness. Energy costs have increased in recent years and this trend will continue. In addition, controlling and optimizing energy consumption is an essential component to reduce the environmental impact of farming that represents high expectations on behalf of consumers. According Vesine E *et al (2007)*, the energy consumption level in swine, poultry and cattle farms is highly variable and heterogeneous according building and management. In order to improve technical recommendation in rabbit farms, this study worked on improving the well-being of the animals, methanisation, photovoltaic, ways to save energy and improve the quality of air. This work should lead to having the building concept evolve into all-in all-out (called System'Duo® in France Avril Group) to meet future challenges in the rabbit industry.

MATERIALS AND METHODS

Reference rabbit building for this study

The shell of the reference building located in France and built in 2007, consists of sheet metal sandwich panels, the framework is structural steelwork, and the roof insulation is made of 5cm-thick polyurethane foam panels nailed to the wooden purlins. There is dynamic ventilation in end walls. There are two identical rooms for an all-in/all-out system. Each room (39.3 x 12.45 m) has a height of 3.4 m at the bottom of the sloping roof and 4 m in the middle. They function independently. The expected temperature in the breeding area is 20°C. A 26 kWh air heater (gas furnace) is installed in each airlock, for cold periods, in order to keep the intake air around 12° C, a second 26 kWh unit is located in the first third of each room. The warm air outlet is directed toward the air inlets. It triggers when the temperature drops to 20°C and stops at 20.6°C. There are six extractor fans set to 8,500 m3/h (measured by anemometer) installed in the end walls to renew air (at cages level and at 3m of height in the building). The farm is also equipped with cooling units (each with a surface of 10 m²) located on the end wall opposite the extractors. The air then enters the 12.7 m long by 4 m wide airlock (from the cooling unit to the room's air inlets). During the summer, the cooling system is used when the inside temperature exceeds 26°C. The atmosphere is managed automatically, all year round, by a temperature sensor located 25 cm above the cages, in the middle of the room. Each room has 4 rows of cages, 620 parity-fattening cages and 420 young females' cages. The capacity, in fattening configuration, is 5200 places. The farmer applies the minimum air extraction setpoint of 0.6 m3/h per kg of live weight. The minimum ventilation in summer is readjusted according to the outdoor temperature and the maximum extraction outputs can reach 3.5 m3/h. The farmer makes 750 AI (artificial insemination) per cycle (42 days) with an average productivity of 17.9 kg/AI per year or 13425 kg sold per batches.

RESULTS AND DISCUSSION

Expenses costs by item

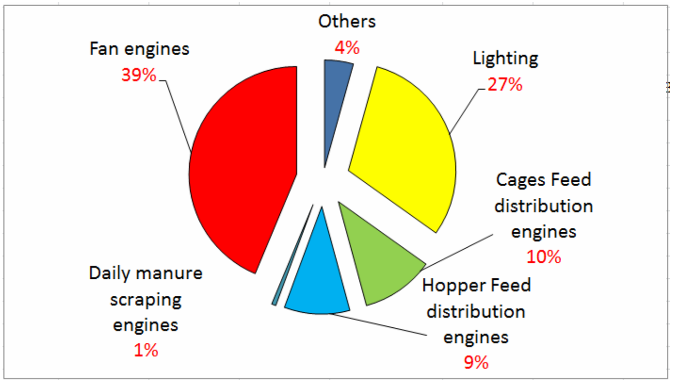

Figure 1: Distribution of electricity consumption

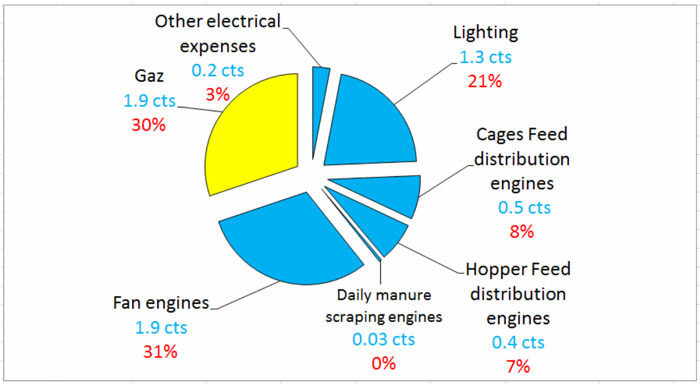

Figure 2: Energy expenses (Euro cents/kg live weight)

The distribution of electrical consumption was estimated based on the nominal power from engines and their operating time. For lighting, each room is equipped with thirty-two 60W neon tubes, switched on between 12 and 16 hours during maternity and 8 hours during fattening (with 50% of neons off).
Ventilation represents the largest expense in terms of electricity followed by lighting and feed distribution (Figure 1). The others expenses item, which mainly consists of the refrigerator, freezer, air heaters, and dosing pumps, accounts for 4%. By comparison, according to a study conducted by ADEME in 2007, heating holds the first place in pig farming at 46% of the electricity bill, then ventilation 39%, lighting 7%, feed 4% and others items 4%.

To make an economic analysis of energy expenses, gas consumption has to be added which represents two tons per year, on average over the last three years (price used for the study €1,000/T of gas and €0,11/kWh). The total energy expense in this building is 6.2 Euro cents/kg of live weight with 3 main items: ventilation, gas and lighting (Figure 2).

Origins of the building's heat losses

A tool was developed for the calculation of energy losses. This tool is adapted to different types of building: tunnels, rigid, and semi-rigid. It takes into account the dimensions of the building, the materials used and the productivity of the workshop to estimate energy losses
The model has enabled to estimate the value of each source of loss, from the characteristics of the reference building during the year. We have identified seven sources of heat loss in the rabbit buildings (Figure 3). The first source of energy loss is related to the room's hot air extracted by the ventilation system, hence the importance of controlling the extracted air output, particularly in winter, according to the needs of the animals. The analysis tool will allow each farm to compare with the reference building in its area and will assist in choosing the kind of building and construction materials. In addition, a thermal camera analysis can complete the approach to validate the quality of the new construction or refurbishing.

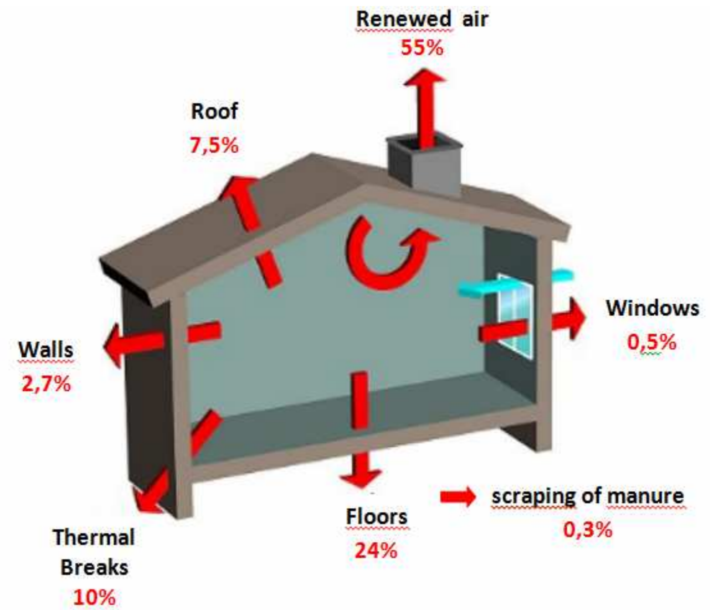

Figure 3: Representation of sources of energy losses in a rabbit building

Ventilation study in the reference building (winter condition, outside Temperature 5°C, weaning period 35 days old, ventilation settings between 0.6 and 1.5 m3/kg of live weight).
We used Solidworks Flow Simulation Software 2013 *(Dassault Systèmes SolidWorks Corp.)* which simplifies the calculation of fluid dynamics. It can simulate heat transfer, flow forces and fluid flow under actual conditions.

Best setpoint temperature of air intake in the room to have a good convection of "fresh" air
Too cold air coming into the room limits the cold/hot air mix and increase health risks to animals. Furthermore, the animals' comfort zone temperature is around 20°C: their maintenance requirements are reduced and a better consumption index is obtained. We tested different intake air temperatures from 6°C to 14°C to obtain 20°C in the room with the best convection. The model allowed us to validate an optimum between 10 and 12°C.

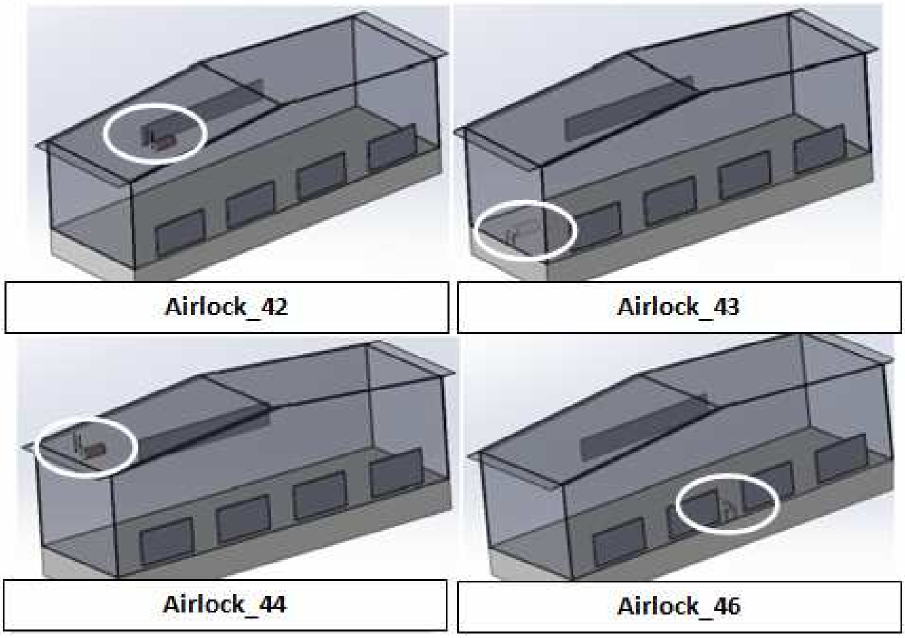

Figure 4: Representation of the 4 heating positions tested in the airlock

Best position of the heater in the airlock room
In addition to maintaining a temperature higher than 10°C entering the room, we have to reach a quality of lateral and vertical air mixing, an homogeneity of the entering air temperature and air flow rate in the airlock less than 1 m/s. The configurations AIRLOCK_42 and AIRLOCK_46 (Figure 4) for these 3 criteria obtain the most satisfactory results. For practical reasons farmers give preference to the AIRLOCK_42 position as AIRLOCK_46 may hinder the circulation of man or trolley.

Best cooling unit opening area in winter in high level
The opening located in the top third of the cooling unit (Figure 5) enables the heater to be integrated along its path and get a fairly homogeneous temperature at the airlock outlet. On the other hand, with a low opening, the main flow does not mix with the heater flow. We see a natural bypass and temperature homogeneity suffers from it with thin layers of temperature ranging from 5 to 13°C.

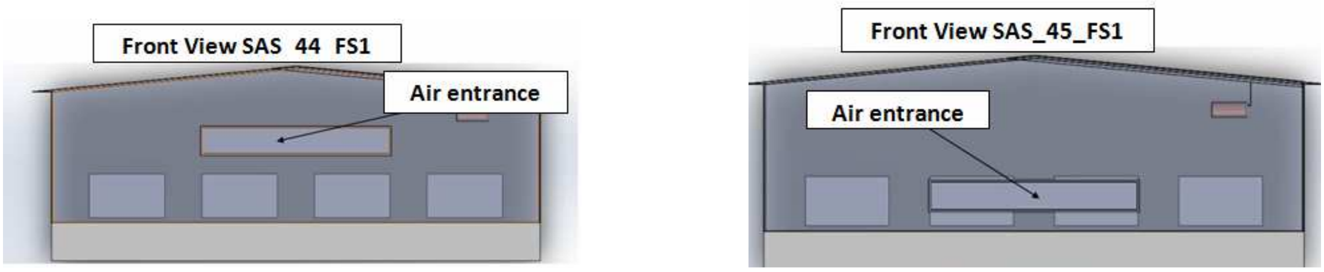

Figure 5: Representation of the 2 cooling opening positions tested in the airlock

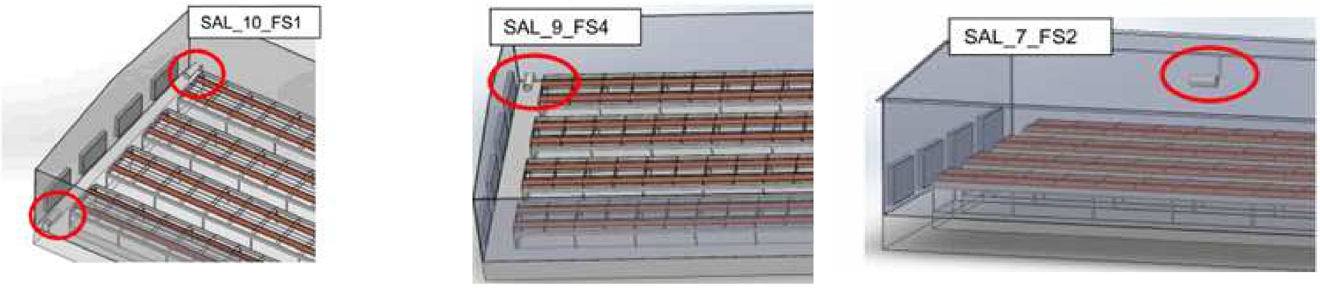

Figure 6: Representation of the 3 heating positions tested in the building

Best position for the heater(s) in the building
Without preheating airlock air, with a mean outside temperature of 5°C, the configuration with two 13kWh air heaters can achieve better homogeneity of air in the room (Figure 6). There is a better convection of air from the first cages but investment is higher (2 heaters). The second and preferred method seems to be the configuration with one 26 kWh air heater on the floor to focus on good convection of the air. The configuration with 1 heater at height in the first third of the room helps maintain a temperature of 20°C at animal level but not to heat the air entering the room. These results need to be confirmed by new similar researches in different building references.

CONCLUSIONS

The main energy saving cost could be obtained controlling the extracted air output (-10% = -0,19 Euro cts/kg live weight) and reducing gas consumption to heat (-10% = -0,19 Euro cts/kg live weight). For this, special attention should be on the floor and thermal breaks insulation. The best position for the heater(s) in the building is on the floor directed toward the air inlets. Regarding the management of air and atmosphere in rabbit buildings, other topics will be of interest like the quantity and size of airborne dust particles in the buildings; trials will initially be done to compare the results with those obtained with other animal productions. In terms of reduction of energy expenses, other means probably exist such as the use of LED lamps which reduces lighting-related electricity expenses. In the future more complex issues will be studied such as the use of heat exchangers, humidity variations or different ventilation setpoints including to improve the winter recommendations. At the same time, a software tool was developed for technicians (web format or tablet computer application) for performing energy balances of a building from its annual production data, equipment and area. This tool aims to offer costed areas of improvement for the farmer and technician in relation to possible refurbishing work.

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Energy Balance and Atmosphere management parameters of building for rabbits

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- Control and optimize energy consumption is essential for farm competitiveness and to reduce environmental impact.
- A good knowledge of air's flows and heating allow to optimize the building concept into all-in all-out (called System'Duo® in French Avril Group)

1 Target

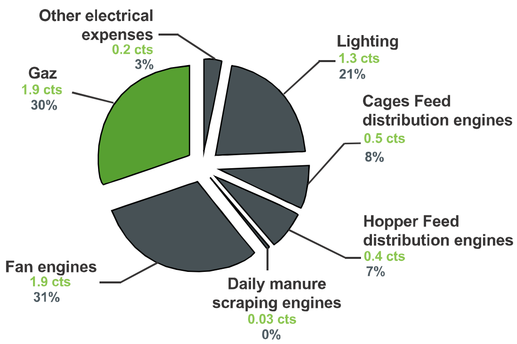
- What are the main energy expenses costs in farm?
- Good knowledge of building's energy losses to reduce them.
- Simulation and optimisation of heat transfer, flow forces and fluid flow under farm conditions.
- What is the target of intake air temperature to reach 20°C in the room with the best convection?

2 Materials and methods

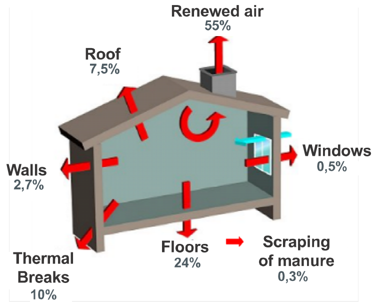
- Reference rabbit building: 4 rows of cages, 620 parity-fattening cages and 420 young females cages. 5200 fattening places.
- All-in/all-out system, sheet metal sandwich panels, steelwork framework, 5cm-thick polyurethane roof insulation, dynamic ventilation in end walls.
- Each room (39.3 x 12.45 m), 3.4 m to 4 m height;
- A 26 kWh air heater (gas furnace) is installed in each airlock and a second 26 kWh unit is located in the first third of each room.
- Six extractor fans set to 8,500 m^3/h and 10 m^2 cooling units
- Minimum air extraction setpoint of 0.6 m^3/h per kg of live weight.
- Solidworks Flow Simulation Software 2013, calculation of fluid dynamics

3 Results

Energy expenses (Euro cents/kg live weight)

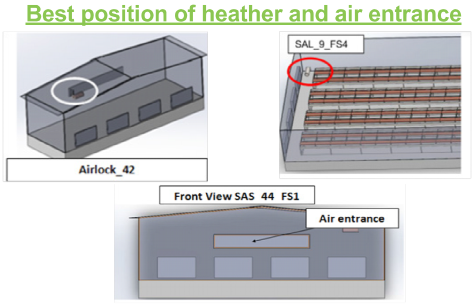


Origins of the building's heat losses



- Ventilation followed by lighting and feed distribution represents the largest electricity expense. The first source of energy loss is related to the room's hot air extracted by the ventilation system
- Best setpoint temperature of air intake in the room is 10 to 12°C

Best position of heather and air entrance



- Best position of the heather is on the top near the air entrance stable and on the floor in the room.
- Best cooling unit opening area in winter is high level.

4 Conclusions

- Main energy saving cost could be obtained controlling the extracted air output (-10%=0,19 Euro cts/kg live weight) and reducing gas consumption to heat (-10%)
- Special attention on the floor and thermal breaks insulation.
- In case of preheating airlock air, best position of heater is high level near air airlock entrance.
- Inside, the best position of the heather is on the floor directed toward the air inlets.