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Research Article

Complex Air Handling of Closed Livestock Buildings

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Abstract

Our current animal husbandry has to meet many conditions, e.g. animal welfare, disease control, environmental protection and of course sustainable economic operation. When modernizing traditional farms or building new farms, if we implement closed housing (pigs, poultry, rabbits), one of the most important factors is to create a microclimate condition close to the environmental optimum for the animal (temperature, humidity, air exchange). Air handling equipment is now available for animal husbandry and can replace previous heating, cooling and ventilation solutions, and their operation can be fully automated. The aim of the work was to theoretically assemble an air handling unit consisting of modular elements, suitable for livestock farms.

Keywords: environment management, microclimate, animal husbandry, technical control, air handling.

Introduction

Concentrated animal husbandry can have a significant environmental impact and can have a disruptive effect on the life of human settlements, while at the same time it places special demands on the creation of conditions that ensure the well-being of the animals, appropriate to their species, age and use. Of course, this is also true for the provision of fresh air, especially for animals kept in closed enclosures. The air exchange of farms is not only about supplying oxygen to the animals and removing gases generated in the building, but also about the energy requirements for ventilation and ensuring a microclimate [1], the risk of contaminants and pathogens that can enter with fresh air, and the dust, infectious and allergenic substances that may occur in the exhaust air, not to mention the possible significant odour effect [2]. In buildings where a large number of people are present in a closed space or where high-purity air

is needed (office buildings, shopping centres, pharmaceutical factories, operating rooms, etc.), the solution already exists for similar problems: air handling equipment, which, with its modular layout, is suitable for fully serving local needs.

These devices have also appeared in animal husbandry (although often only some of their elements are isolated), but complex solutions have also become available.

The most important functions in livestock buildings are an efficient and energy-saving cooling [3] and heating system, draft-free air exchange, detection of hazardous gases in the building, filtration of fresh and exhausted air [4], and full automation of the system [5].

The work presented what air treatment solutions were prevalent in average Hungarian livestock farms and what new solutions could be offered to farmers instead for the reconstruction of buildings or the design of new buildings.

Material and methods

The examples to be presented are based on the characteristics of a traditional broiler chicken farm, a recently built rabbit farm and a model room demonstrating what can be considered modern

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pig farming technology. An effort was made to supplement or even replace the partial solutions observed in these places, relying on examples from literature data. We have collected our own experiences and the shortcomings of current practice during our visits to certain technologies, and then based on available technical solutions; a recommendation has been made for an air handling system built from modules. At the end of the material, a complex system based on modular elements is presented.

Broiler chicken farm, Hodmezovasarhely

The complex consists of more than 40 years old, traditional brick-walled buildings covered with corrugated slate. The plastered walls are not thermally insulated, and the ceiling is made of wood fibre panels and is also uninsulated. Fresh air enters through the air intake windows on the side walls. The used air is extracted from the building by high-performance axial fans. The evaporative cooling panels can cool the incoming air by 5-6 °C in summer. In cold weather, the main temperature of the room can be raised with gas-powered hot air blowers (Figure 1) and gas infrared heaters. A temperature sensor located in the room controls the heating and ventilation.



Figure 1. Natural gas-powered hot air blower

Rabbit farm, Berettyóújfalú

The rabbit hutch was built 6 years ago from 10 cm thick steel sheet covered polyurethane sandwich panels. Ventilation is provided by air inlets and axial fans similar to those in a poultry house, but the air flows in the room not longitudinally (like a tunnel) but transversely. The air can only be

cooled with evaporation panels (Figure 2) if necessary.



Figure 2. Air intakes and evaporative cooling panel in the building wall

The ventilation is only operated by a temperature sensor or a timer, although the installed control unit could also receive signals from other sensors.

Swine technology showroom, Mezőhegyes

The pig farm technology shows the elements of a system widespread in Hungary. The opening and closing of the air inlets can be automated; the used air is discharged in a controlled manner through a chimney led through the ceiling and roof. Ventilation and heating are controlled by a central unit (Figure 3) based on the signals of temperature sensors.

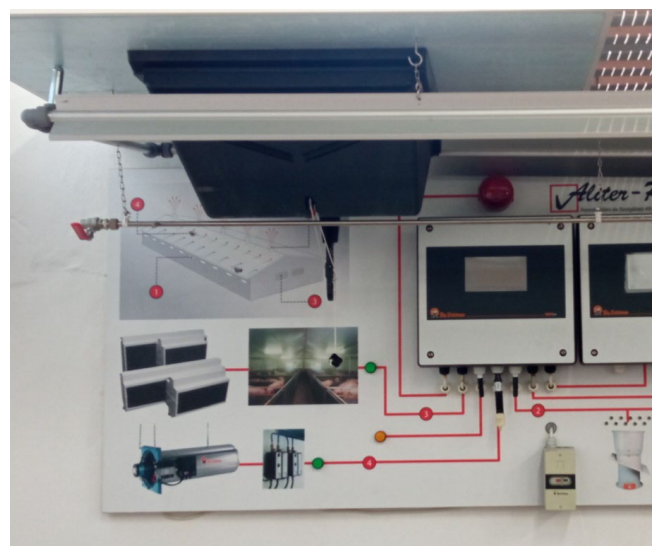


Figure 3. Model of pig farm climate control

Results and discussion

The locations examined, which reflect average conditions in Hungary, did not have all possible technical conditions for air treatment. They tried to create different conditions depending on the animal species kept, but they could not meet all requirements. Perhaps the pig farm technology had the most elements that could create favourable conditions for the animals, disease control, the environment and the workers.

Supply of ambient air

The temperature and relative humidity of the outside air rarely match the needs of the given animal group, and the incoming air requires treatment [6].

In the case of broiler chickens, the room temperature requirement changes continuously from the time the chicks are received to the time they are sold (32°C – 24°C). This higher value is ensured by natural gas-powered radiators for most of the year, while the lower value is attempted to be achieved by evaporative cooling panels built into the wall during the summer. The relative humidity of the air cannot be controlled. The filtering of the incoming air has not been solved, and at best a grid on the air intakes prevents the entry of birds and other animals, and there is no possibility of filtering insects, dust and other floating particles. Poultry farms are exposed to avian influenza infection throughout the year, but especially during the autumn and spring wild bird migrations.

Depending on the weather, the incoming air in the rabbit farm is also cooled with an evaporative cooler. There is neither a need nor an opportunity to heat the air according to the needs of the species. The relative humidity cannot be modified. There is a mosquito net on the air inlets to keep out mosquitoes that spread a dangerous infectious disease of rabbits (myxomatosis, RHD). Filters do not prevent the entry of environmental dust.

In pig farm technology, the air inflow is similar to the broiler farm solution, and here too, the incoming air must be heated (natural gas-powered hot air blower) or cooled (evaporative cooler) according to the age and needs of the animals. In addition to the air intake openings in the farrowing buildings, it is possible to introduce air through diffusers (perforated plate) placed on the ceiling, thus avoiding the formation of drafts. Air filtration is not implemented here either, although in pig farming, due to the national threat of African swine fever, every effort is made to prevent the entry of infectious substances in other ways.

Condition of the air in the building

In the locations visited, the air in the room is determined by the temperature, relative humidity

and current physical cleanliness of the incoming outside air. When designing the internal environment, the air can be cooled or heated to a limited extent, but the system does not take into account the creation of a relative humidity that meets the environmental needs of the animals. The humidity of the air entering the building may be higher or lower than necessary depending on the temperature, but it does not take into account the moisture emitted by the animals, the humidifying effect of evaporative coolers, and the water vapour released from urine and manure.

When used as intended, the composition of the gases in the air constantly changes. When buildings are used as intended, the composition of the gases in the air constantly changes. Ammonia, hydrogen sulphide, and occasionally methane and other greenhouse gases are released from urine and manure [7,8,9,10], which, if they accumulate, worsen the production indicators of the animals and have an adverse effect on the well-being of the animals and workers, and in more serious cases, on their health. Due to the imperfect operation of natural gas-fired heating devices, dangerous carbon monoxide and sulphur compounds can also enter enclosed spaces. The odours from livestock buildings [11] can be a significant nuisance for both workers and residents of nearby settlements. A similar adverse effect is caused by airborne particles, which include feed dust and depending on the species, shed epithelial cells, hair and feather fluff. Any of these can also have an allergenic effect.

Exhaust air from the building

The exhaust air leaving the building carries the aforementioned gases (and their odours), dust, and other airborne particles [8], which are polluting in themselves, but in unfavourable animal health situations, the infectious agents associated with them are also released into the environment [1]. Therefore, it may be appropriate to filter not only the fresh air, but also the exhaust air.

Traditional fan ventilation is also an energy issue [12]. In the summer, we regularly remove air that has already been cooled with increasingly expensive energy, and in the winter, we regularly remove air that has been heated, which wastefully cools and heats the building environment [13-15].

Complex air handling

The design of the air handling unit (Figure 4) is as follows: The fresh air inlet (red arrow) starts with a damper on the connecting branch (as well as at the end of the other branches, so that the air handling unit can be closed in the event of a break in operation), then three stages of filtration are implemented with one coarse and two fine filters.

The air is then fed through the sound attenuating element into the heat recovery unit, where the

heat recovery efficiency is 85% in winter and 80% in summer.

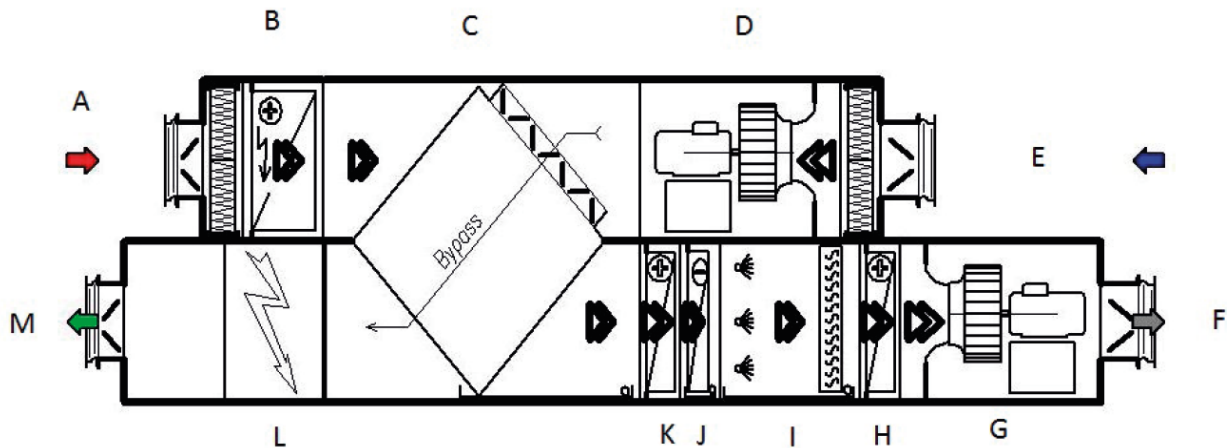


Figure 4. Schematic drawing of an air handling unit (based on Bodnar et al., 2019 [13])

Legend: Red arrow (A): fresh air inlet with filters, B: electric heating unit, C: heat exchanger, D: exhaust fan, Blue arrow (E): exhaust air inlet with filters, Yellow arrow (G): treated fresh air outlet, H: inlet air fan, I: heater calorifier, J: humidifier/dehumidifier, K: cooler calorifier, L: control unit, Green arrow (M): exhaust air outlet, The direction of the arrows indicates the direction of air flow.

After heat recovery, the air is fed into a DX type gas-fired chiller (3 of which are designed for cooling only), but is configured to operate in heating mode in winter, but this is not a factor in the design. The chiller is also equipped with a droplet separator to remove condensed moisture from the air stream, so that approximately 100 kg/h of condensate is discharged in summer.

EC fans with pressure chambers can be chosen as fans due to their good efficiency and high air flow compared to the pressure rise, which is necessary, since the resistance of the air handling unit's own components is quite high compared to the system.

From here, the blown air (green arrow) exits the equipment through a sound-absorbing element into the interior of the building.

It is worth implementing three-stage filtration in the machine's exhaust branch, a fine F7, a fine F9, and a C6 carbon cartridge filtration. The carbon filter reduces unwanted odors (hazardous gases), thus reducing environmental pollution, and the two fine filters protect the equipment. A separate coarse filter is not placed in the machine's exhaust branch, as it is located in a separate unit in front of each air handler. The pre-filtration is carried out in several stages, starting with a larger-meshed bird net, followed by a finer screen filter, and then a G4 bag filter, which can be classified as coarse quality class [16].

The reason why so many filtration stages are needed is because when keeping rabbits and broilers, not only dust-like contaminants are released into the air, but also the animals' shed hair or down feathers [17]. If we did not capture it in several steps, the filters protecting the machine

would become clogged very quickly, as the hair and down would collect on the surface of the filters and form a felt layer on them, which would prevent air flow. Since the separation of hair and down feathers is not possible with centrifugal separation units, as they are too light compared to their surface, and washing would produce a lot of hazardous waste, the only option is to install filter walls and clean them frequently.

After filtering, the air re-enters the heat recovery unit of the air handling unit and releases the stored heat to the fresh air. If required, UV lamps can also be installed in the air ducts for disinfection purposes [18]. Before exiting the unit, the air passes behind the built-in cabinet of the equipment's automation, and then exits through the frost protection damper to the outside.

It is worth determining the temperatures, capacities and humidity levels for the air volume so that the large amount of heat and moisture released by the animals in the building can be removed according to needs.

The air handling unit is designed with a stainless-steel interior to prevent corrosive materials from corroding its surfaces. Due to its outdoor location, the frame and panelling are usually provided with increased thermal and sound insulation. For the same reason, the entire unit also has a protective roof and a mounting frame without levelling feet, with lifting lugs, so that it can be placed on a pre-prepared support structure that lifts it above the snow line.

The automatic unit controlling the air handling unit and the control dampers is located in the exhaust branch, which is operated in the air volume control function. If the sensor indicates that the heat

recovery unit is frozen, the bypass branch in the heat recovery unit opens and it defrosts itself.

The sizing of the air handling unit of the livestock farm often shows that it does not meet the EcoDesign requirements, but here it is a matter of satisfying the technology [19], which the regulation makes an exception to.

The specific sizing of the air handling unit modules for a given location is possible based on knowledge of the farm building and livestock.

Conclusions

The ventilation system designed based on on-site measurements is fully capable of satisfying the microclimate needs of a large number of livestock. Due to the high cooling/heating thermal capacity of the planned ventilation system on the examined farms, it can only be operated in conjunction with the modernization of the current electrical network.

In addition to meeting the needs of the animals, the primary consideration is the protection of ventilation system elements from corrosive environmental factors (vapour, ammonia, hydrogen sulphide, etc.).

In stables built according to traditional standard designs, the subsequent design of the ventilation system included in our work can only be solved with certain compromises due to the technological characteristics of animal husbandry.

The treatment of the exhaust air presumably significantly reduces the environmental load (dust, hair, feathers, noxious gases), but detailed, reliable data on its effectiveness are not yet available.

In the case of buildings housing rabbits and broiler chickens, the removal of rabbit hair or feathers from the exhaust air is difficult, and is probably only possible by using grid filter inserts with decreasing mesh size. The water curtain solution would pose additional technical problems due to the large amount of hazardous waste (washing water) generated.

The technical solution included in the plan not only creates a favourable production environment for the rabbits, but also creates an optimal working environment for the workers there.

The operation of the presented air conditioning system is more labour-intensive than the currently widely used fan solutions, but if livestock keepers wish to comply with the increasingly stringent requirements of animal welfare and environmental protection, it can be recommended to incorporate it into the technical solutions of newly designed farms.

The economic calculation of the investment and operating costs of the air handling equipment requires further studies.

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