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THE APPLICATION OF POULTRY BEHAVIOUR RESPONSES ON HEAT STRESS TO IMPROVE HEATING AND VENTILATION SYSTEMS EFFICIENCY

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ABSTRACT

Poultry is particularly vulnerable to heat stress conditions. Birds have no possibility to loose the heat by sweating, thus losses by convection and respiration remain the only mechanisms for taking the heat out of them. Whereas there is common consensus among scientists and growers on optimum ambient temperature range for well feathered 4-6 weeks old broilers, there are considerable differences in evaluation of potential negative effects of their exceeding in terms of production result, health status or animal welfare.

There is no consensus on optimal temperature range for young chicks in first 2-3 weeks of housing. The values of recommended ambient air temperature for 1 day old chicken change from 35 to 30°C. There are also considerable differences in suggested differentiation between ambient air temperatures and the ones directly under brooder. First weeks growers usually try to keep the temperature in a building close to its upper recommended value, to avoid potential problems with chilling which can be caused by many potential factors (from health status and appetite of the birds, quality of food through outside climate to inefficient heating and ventilation systems or their improper control and management). In result chicks are often overheated with all negative consequences.

According to many poultry consultants chicken themselves and their behaviour in particular are the best indicator of potential problems with overheating or chilling.

In the paper two cases were studied: reaction of young poults kept under brooders to apparent overheating and adult birds reaction on sudden changes in effective temperature at hot summer weather. Short term air and operant temperature as well as air velocities measurements were also carried out to identify the effective temperatures at the time of experiment.

The results of research suggest that in order to succeed in broiler housing growers should be more capable to interpret chicken behaviour than spend time reading the thermometers. Another important conclusion is that all the recommendations given by ventilation or heating equipment manufacturers should be continuously checked in practice since it is impossible to predict all the factors which can affect the thermal comfort of the birds.

Key words: poultry housing, ventilation, heat stress, ventilation, heating

INTRODUCTION

Temperature is commonly assumed to be the most important environmental factor influencing chicken health, behavior and production results. There are various official recommendations, given typically by producers of genetic material, what exactly the optimal range of temperature should be (Tab. 1). The temperatures recommended by them are usually significantly higher than the ones obtained in research carried out under precisely controlled conditions. In such research [8] found no difference between health status, weight gain, feed conversion for chicken kept at three temperature programs:

- 35.0°C in week 1, 32.2°C in week 2 and 29.4°C in week 3,
- 32.2°C in week 1, 29.4°C in week 2 and 26.7°C in week 3,
- 29.4°C in week 1, 26.7°C in week 2 and 23.9°C in week 3.

There is also no agreement on optimal temperatures for young chickens among authors of popular manuals on poultry housing. The recommended temperatures under brooder for a day old chicken start from 30-32°C [18] ending up at a level of 35°C [21].

Table 1. Typical range of temperature values recommended by genetic firms

Age (days)	Space heating (°C)	Radiant heating (°C)	
		under brooder	outside brooder
0-7	31-30	35-32	25-28
8-14	30-27	32-29	24-25
15-21	27-24	29-26	23-24
22-28	24-21	-	24-21
29-until sale	20	-	18-21

The reason for such differentiation in optimal temperatures recommended for chicken is fact that temperature sensed by animals (often called an “effective temperature”) depends not only on temperature of the air but also on all other factors which affect heat exchange between animal and its direct neighbourhood – air temperature, humidity and velocity [17], type of the flooring material [16] its wetness [9] or heat radiation exchange between animals and building walls and ceiling. Another group of factors which affect effective temperature is connected with animals themselves as well as the way of their housing and management. Most important issues here seem to be: animal age, their health status, appetite, energy input in feed [4] or diurnal activity [19]. Sex, genotype as well as goal of selection appeared to affect relation between temperature, weight gains, feed efficiency protein and fat deposition [13, 14] and probably also the temperature sensed by animals. At radiant heating there might be a serious problem with providing at the same time for right operant temperature range under the brooder and its value in ambient air.

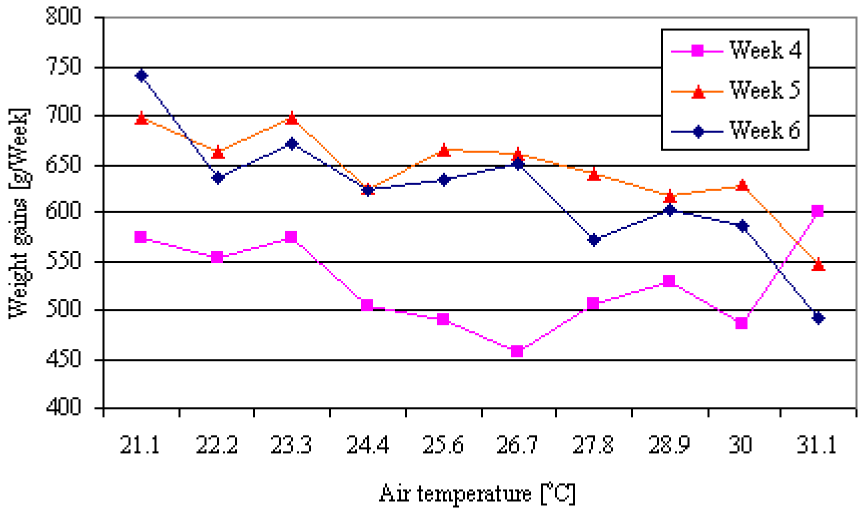
Under these circumstances North and Bell [18] consider thermometers as a poor tool for measuring the temperature sensed by chicken and suggest to use them only the first 2 days after the chicks are placed under the brooder. They can be removed then and chicken behaviour itself should indicate the grower how they actually sense the temperature.

There is not so difficult to provide for right temperature range for older broilers. There is common consensus among scientists, consultants and growers on optimum ambient temperature range for well feathered broilers. Still, there are considerable differences in approach to evaluation of potential negative effects of heat stress on 4-6 week old broilers. There is continuous genetic selection in broilers in order to get the best production results and meat quality. Unfortunately, improvements in production results are usually associated with narrowing birds thermo neutral zone and increasing their vulnerability to heat stress [14]. The data on optimal temperature range obtained 15-20 years ago need to be updated.

Most recent research data on effect of temperature on weight gains of Ross x Ross male broilers in week 4, 5 and 6, given by May et al [15], are presented in Figure 1.

As it can be seen there was no clear trend for weight gains in week 4. For week 5 and particularly 6 however there was dramatic reduction in weekly gains when air temperature raised above approximately 21 to 23.5°C range.

Fig. 1. Effect of air temperature on weight gains of Ross × Ross male broilers



The data presented in Figure 1 were obtained for keeping temperatures at constant level. Actually the temperatures never remain at very high level for very long. To more accurately model the real thermal conditions Knight et al. [11] assumed that a few days periods of high temperatures were followed by the periods of normal temperature. There were also attempts to evaluate effect of thermal stress at real weather conditions. Comparing to Autumn period, Yalcin et al. [23] found significant effect of Summer weather in Turkey on worsening weight gains and feed conversion even as early as in week 1-4.

METHODS AND RESULTS

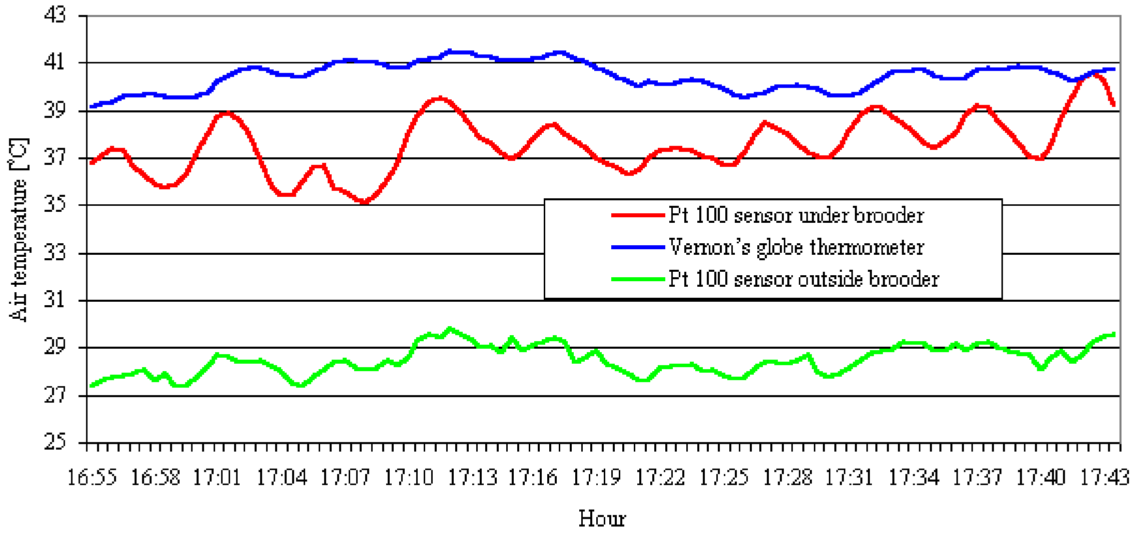
Heat stress under the brooder

Radiant heaters (brooders) are probably the most recommended type of heating equipment for broilers. They are very effective for two reasons:

- they utilize heat of radiation to directly warm up the litter and the birds, thus saving heat energy comparing to spatial heaters which are heat up all building space,
- they provide effective temperature differentiation under the brooder itself and at zones out of its reach, allowing the birds to find the areas with temperature which suits them best.

To evaluate the effective temperature under the brooder usually operant temperature, understood as a resulting of air and radiant temperature is measured. For its measuring Vernon’s globe thermometer is recommended [1]. It consists of hollow 150 mm painted black copper sphere with temperature sensor inside. The ambient air temperature is commonly measured by uncovered temperature sensors
In Figure 2 a typical courses of air temperatures for 5 days broilers, measured under brooder with Vernon’s globe thermometer with resistor based Pt 100 sensor and with standard uncovered Pt 100 sensor were presented. The accuracy of both Pt 100 sensor used was ±0.3°C at 0°C. Additional Pt 100 sensor was used to measure the temperature outside the brooder reach.

Fig. 2. Typical courses of air temperatures measured under brooder with Vernon's globe thermometer and standard uncovered Pt 100 sensor under brooder and outside it [12]



Average temperature under brooder measured with Vernon's globe thermometer was 40.5°C, with minimum 39.1°C and maximum 41.5°C. Considerably lower were temperatures measured by uncovered sensor. Much lower was the temperature measured outside the brooder with average 28.5°C, minimum 27.3°C and maximum 29.8°C.

Black globe thermometer seems to quite well represent chickens sensing of temperature since values of its convective heat transfer coefficient as well as emissivity are closer to the same values for chicken body than the ones of standard temperature sensors [1]. Vernon's globe has high time constant which makes it more representative for chicken remaining for considerable time under brooders then the ones which are in move. This is also the reason why fluctuations of temperatures measured with Vernon's globe were much lower than fluctuation for uncovered sensor Pt 100. Respective differences between maximum and minimum temperatures were 2.4°C and 5.5°C respectively. The readings at Pt 100 changed immediately after switching the brooder on or off but these considerable changes probably did not reflect accurately sensing temperature changes by birds.
Many equipment manufacturers recommend to control brooders operation by means of black globe thermometers. The problem than is with providing right ambient temperature which often causes a lot of problems. With outside temperatures significantly below 0°C, time of brooders operation required to keep ambient temperature at a recommended level is considerably longer than to keep it at the same level at Spring, Autumn, or particularly Summer. In effect the differences between ambient air temperature and operant temperature under brooders are much higher.

A better solution seems to be using standard sensors, which are located outside the brooders and measure ambient temperature. This way of control is also quite often recommended by manufacturers and most often used by growers. In this case the air temperature in a building is set up at a level of 3-7°C below the recommended air temperature under brooder.

In broiler house for which the temperatures were illustrated in Figure 1, the brooders were thermostatically controlled with 4 sensors located at long axis of the building measuring ambient air temperature. Their average reading from last 24 hours was 27.3°C, close to maximum of the range given at Table 1.

5 day old birds exposed to average temperatures of about 37.6 or 40.5°C operant temperature did not accept this kind of thermal conditions (Fig. 3).

Fig. 3. Distribution of 5 day old chicks in a building with particular reference to their positioning under brooders [12]

There were only single chicks remaining under the brooder. Since at that age birds have usually very different thermal needs, their behaviour suggests that the temperature sensed by them was rather closer to 40-41°C measured by black globe thermometer than 37-38°C measured by uncovered temperature sensor. Similar laying arrangement was found in all the building.

The ambient air temperature at birds zone was at its maximum for this age (27-29°C). The weakest and strongest birds had to stay at a uniform temperatures, probably to high for many of them. On the other hand the weakest birds which probably preferred a bit higher temperature were not able to find the most suitable location.
Two most important benefits connected with radiant heating application were lost:

- birds were not given freedom of choice of most suitable thermal conditions, what could negatively affect their health welfare and growth,
- brooders served as spatial heating with excessive energy used.

The temperatures under brooders have not been monitored, nor just checked by the grower. Brooders were positioned exactly at the height recommended by manufacturer with assumption that their location should provide for right temperature difference between operant temperature under brooders and ambient temperature in the building.

This observation corresponds very well with research work of Peiper et al. [20] who found regular pattern of birds migration (out of the brooder after their switching on and toward them after they were switched off). According to the authors the reason for this migration was locating the brooders too low, although exactly at the height recommended by manufacturer.

Since their dependence on outside temperature, wind speed and direction, there is probably no way to provide stable relation between operant temperature under brooders and ambient temperature.

Thermostats are necessary for brooder operation control, particularly in first two weeks when ventilation may be kept at relatively constant level. It should be supervised however by the grower who on the basis of thorough everyday observations of chicks behaviour should be always ready either to adjust the height of brooders or the temperature setting at a thermostat.

Heat stress at hot summer weather

Exhaust ventilation systems are the ones most commonly used in intensive production of broilers. The underpressure in a building is usually created by fans which are placed in the ridge when air inlets are in both walls of the building or in one of the wall when inlets are positioned in the opposite wall. At mechanical ventilation systems fans are responsible for the total ventilation air exchange. The distribution pattern of ventilation air in the building depends mostly on technical solution and positioning of the air inlets. At moderate climate air high speed air inlets are typically used which are placed high in the walls to be able to direct the stream of the incoming air parallely to the ceiling. The solution significantly reduce the risk of cold drafts at animal zone. Another solution of air inlets which practically eliminate the risk of cold drafts at floor level is using for this reason all or most of the area of ceiling which in this case has to be permeable [10].

The above solutions of ventilation work very well in most of the year when outside temperature are at low, medium or even relatively warm weather. When outside temperature exceed a level of 23-26°C, it starts to be difficult to keep indoor temperature within the limits of thermoneutral zone by air exchange alone. In this case some additional methods of lowering the effective temperature in a building are being used.

One of the most common method of lowering the effective temperature in poultry housing under hot summer temperatures is to increase air velocities at floor level to improve convection heat exchange between birds and adjacent air. This method is supposed to be efficient when ambient air temperatures are lower than about 37.8°C [22]. The additional benefit from directing the air stream to birds zone is preventing quite common for hot summer conditions, temperature lift at floor level [6].

The negative consequence of high speed at floor level should be increase of ammonia volatilization from litter and in effect its emission from the building. The total increase in ammonia emission for poultry housing at moderate climate should not be significant due to only temporarily need for applying such methods.

The system most commonly used for increasing air velocities building for broilers is tunnel ventilation in which the exhaust fans are placed at one end of the building and air inlets at the opposite end. The air is supposed to move with air velocity at a level of approximately 2 m/s through all the length of a building, thus cooling the birds by convection.

The main problem with is very long way for a fresh ventilation air from air inlet to exhaust fans. Incoming air on its way through building is being heated up by the heat produced by the birds as well as getting polluted by toxic gases. This favors the birds which are close to air inlets comparing to the ones remaining on exhaust ventilation side. To provide against accumulation of heat and toxic gases in ventilation air, its velocity must be kept at a level of 1.5-2 m/s. Still even at air velocity of 1.85 m/s in building 120 m long, the temperature difference between its front and rear side may approach 3°C [7]. For large birds tunnel ventilation is recommended when outside temperature exceeds 24°C with the minimum of 3×120 cm diameters fans running [5]. The average air velocity at bird level will be then reduced to about 0.8 m/s and temperature difference between front and rear side of the house given in example above, can reach 7°C.

As one of the most serious problems connected with tunnel ventilation Czarick and Tyson [7] mention broilers migration toward the air inlet. It well proves their preference for colder and cleaner air but also leads to overcrowding at the front side of the house. To protect against this kind of birds migration air deflectors which increase local air velocity are suggested [7] as well as migration fences which physically prevent birds to move at larger distances [3].

Much better solution from animal welfare point of view seem to be suspended below the ridge paddle fans which blowing the area down, create circular areas of high air velocities at bird level. The air speed increases from about 0.5-1.0 m/s directly below the center of the fan, reaches its maximum of 1.5-2.0 m/s at about 3 m from the center and then slowly goes down to 0.5-0.9 m/s at 8 m from the fan center [2]. Such profile of air velocities (from 0.5-2.0 m/s at a radius of 8 m) encourage broilers to move looking for the thermal conditions which would best suit their needs. This kind of birds movement under the paddle fans was found by Bottcher et al. [2]. At indoor temperature 25°C, 0.5 kg broilers were at the beginning avoiding circular area directly under fan where air speeds were the highest. After only 5 minutes, most of these empty areas have been filled by birds what can suggest that some of them preferred low effective temperature directly under fan and somehow managed to get there.

In contrast to bird migration representative to tunnel ventilation this kind of migration take place at very limited area with relatively broad spectrum of thermal conditions and because of that should not lead to overcrowding.
Still another technical possibility of increasing air velocities is the design of separate air inlets for cold and hot weather. Cold weather air inlets might be high speed ceiling or wall inlets directing the incoming air parallely to the ceiling surface whereas hot weather air inlets are to direct the incoming ventilation air to floor level (Fig. 4).

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Fig. 4. Laying hens barn with separate air inlets for cold and hot weather

Still another solution, quite often used by Polish growers in buildings for broilers is placing in one side wall the inlets which make it possible according to requirements to direct the incoming air down or up by changing the position of the inlet cover.

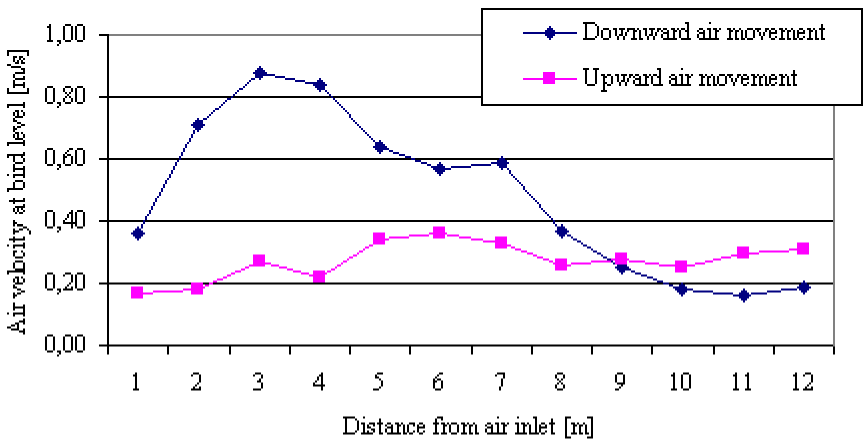
Fig. 5. General view of the building with 2 side walls visible with upward/downward air inlets in one wall and exhaust fans at the other

As it can be seen all air inlets are positioned at one side wall with all exhaust fans located at the opposite wall (Fig. 5). In cold or mild weather air inlets are positioned up to the ceiling. In hot summer weather the air stream is directed down to the birds.

To find out the behaviour response of broilers to cyclical changes in air velocities and associated effective temperature, once an hour the positioning of air inlets was being changed from upward to downward and opposite. An experiment has been carried for 2 hours (from 14:00 to 16:00) in 2 succeeding days at 2 identical buildings 12 m wide and 100 m long with approximately 20 000 (1.6-1.8 kg) broilers each [12]. The outside temperature at a time of experiment was at a range of 29.6 to 32.1°C. Total air exchange by fans was at about 180 000 m^3/h.

In Figure 6 distribution of air velocities at bird level depending on their distance from the air inlets has been shown. The momentarily measurements were taken at a time of experiment in one selected cross section of each building with 1 thermo anemometer FV A645-TH3, AHLBORN, Germany, with accuracy of measurement ±0.03 m/s in range 0.1-0.5 m/s and ±0.01 m/s ±3% of measured value in range 0.5-3.5 m/s.
The values given at figure 6 are average from 2 measurements.

Fig. 6. Distribution of air velocities at bird level depending on their distance from the air inlets [12]



As it can be seen, directing air inlets downward gave particularly spectacular effect at first 7 m from air inlets wall. The average air speeds for this distance where respectively 0.66 ±0.18 m/s for inlets positioned downward and 0.27 ±0.08 m/s when they were positioned upward. From 9th meter the average velocities measured for inlets positioned upward became higher than for their downward positioning with respective values 0.29 ±0.03 m/s and 0.20 ±0.04 m/s.

We have not observed any significant birds migration connected with changing position of the air inlets. Most common change in behaviour pattern concerned drinking and was particularly well seen first 10-15 minutes after changing position of air inlet. There were 4 drinking lines at a building with cup drinkers positioned symmetrically to its long axis.

An experiment started with air inlets positioned upward. Birds behaviour was dependent on a distance of drinking lines from air inlet wall. At first two of them immediately after directing incoming air downward most of the birds started to step away of the drinking cups and taking lying position (fig. 7b versus 7a).

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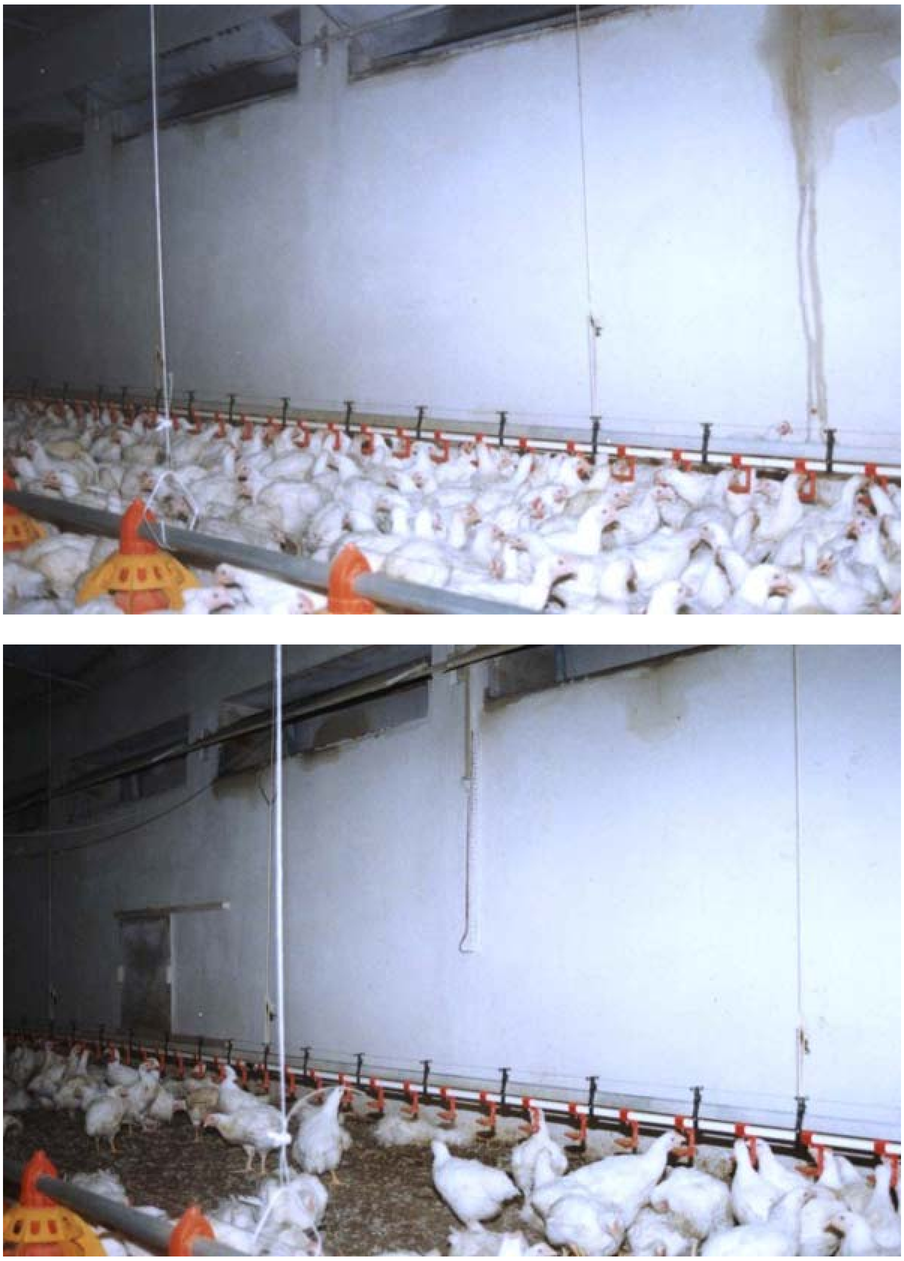
Fig. 7. View of the drinking line closest to air inlet wall: a) air inlet positioned upward, b) air inlet positioned downward



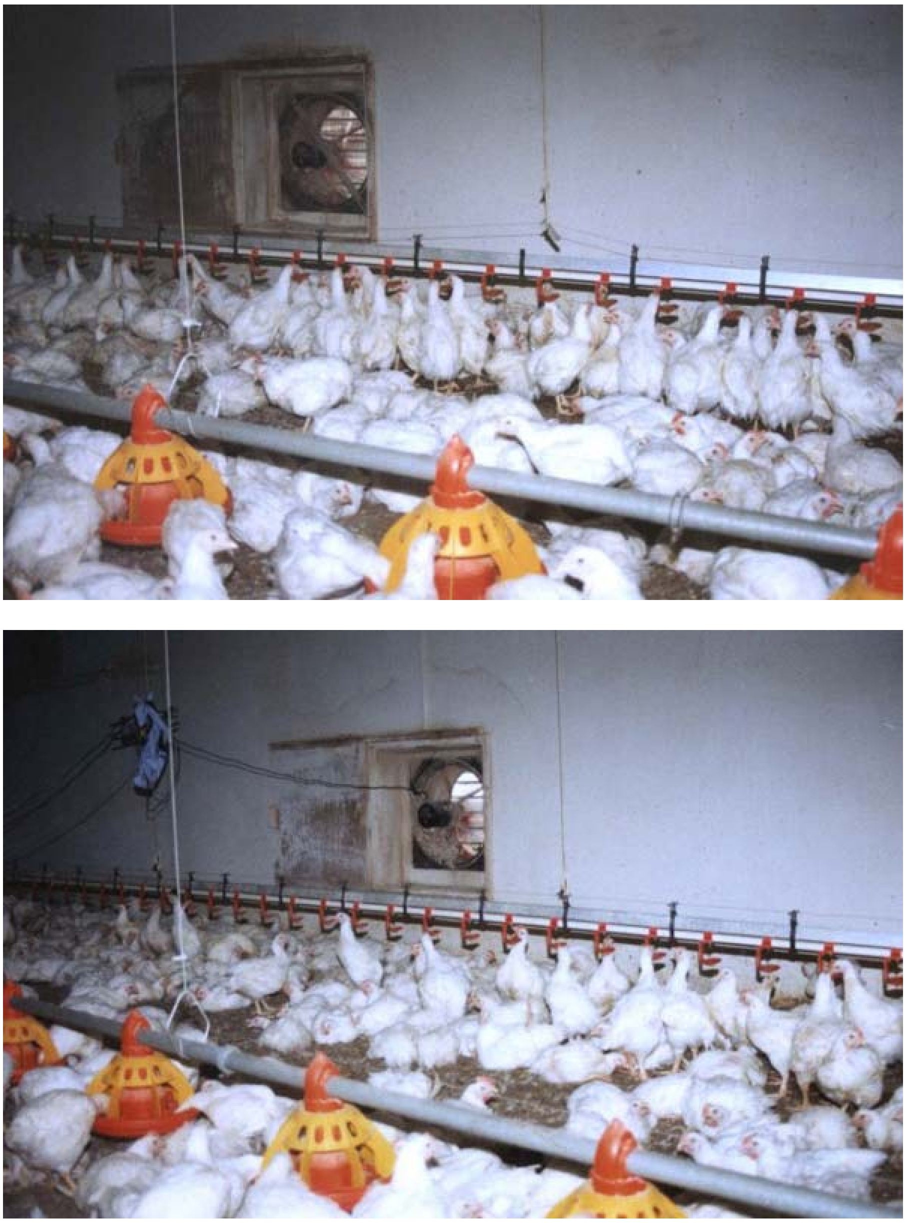
After directing air inlets upward birds slowly started to get up and tried to reach the drinkers again.

Quite opposite action took place at fourth drinking line (close to the fan wall) (Fig. 8) where directing incoming ventilation air downward caused more birds try to approach drinkers with quite often more than one broiler being waiting for its time to drink.

After changing the position of an air inlets upward number of birds occupying the drinkers significantly decreased.

The were no significant effects of air inlet positioning at 3rd drinking line.

Fig. 8. View of the drinking line closest to exhaust fan wall: a) air inlet positioned downward, b) air inlet positioned upward



Behaviour responses of the broilers on changing the direction of ventilation air incoming to the building seem reflect very well changes of air speed at bird height.

One possible explanation of such sudden changes in behaviour could be that under heat stress birds are looking for some additional contact with water not only for drinking but also for wetting themselves. As a result of increasing air velocity effective temperature in a building decreases, heat stress is reduced and birds, feeling sudden heat stress relief, have no more need to look for using water for reasons other than drinking. When air speed goes down, heat stress becomes unbearable and birds are looking back for some additional possibility to reduce its effects.

Described above changes in broilers behaviour seem to be dynamic (momentarily) response to increased or decreased heat stress, what means that increase or decrease of air speed should not have significant effect on daily water consumption. In fact it was not possible to see any significant differences in number of bird approaching drinking lines where position of the inlets were upward or downward for considerable long time. Short time of birds exposition on changes in thermal environment could be possible reason for no visible signs of bird migration toward air inlets after their downward positioning.

When air is sucked downward through the inlets air velocities at birds level are not only substantially higher but also much more differentiated than in case when it comes upward ($S.D_d = 0.26°C$ versus $S.D_u = 0.06°C$). This differentiation at cross section of a building could probably lead to some more stable pattern of behaviour response of the broilers i.e., their migration from the fan to inlet wall of the building at high outside temperature if only the direction of incoming air would be consistently downward. Such a bird migration was not however evaluated at a time of experiment. If it took place it would probably look more like slight bird movements found by Bottcher et al. [2] for paddle fans than migration which takes place at tunnel ventilation with all its negative consequences.

The observations of momentary changes of drinking birds behaviour alone suggest that directing incoming air downward is more beneficial since it improves thermal environment to most of the birds in the building. Slightly higher effective temperatures were only in a 2-3 m zone in a close neighbourhood of the fan wall and they did not, according to grower, negatively affect broiler health or behaviour.

DISCUSSION

The research was initiated by observing broilers behaviour responses during routine inspections of thermal environment and efficiency of technical systems used for its control. On the basis of preliminary bird behaviour observations, some short term experiments were carried out and their results have been documented. Their main purpose was to illustrate interrelations which exist between technical solutions of heating and ventilation system and the way they are managed from one side and appropriate animal reactions from the other.

Another goal was to find out if it is possible to use birds behaviour responses on heat stress to improve heating and ventilation systems control.

The results of research suggest that there is not only one way relation between ventilation and heating system and birds behaviour. Broilers reaction to poor thermal conditions often affect the grower response which is not always adequate to what the birds actually need. Resulting changes in management sometimes can make the situation even worse.

What seems to be particularly important is to make the grower conscious that all recommendations on type of ventilation and heating equipment, their positioning or thermostat settings make only some reference level which should be continuously verified by thorough observations of birds behaviour.

Also of importance is to make the grower to realize that his interpretation of birds behaviour does not always have to be adequate since his personal experience is usually limited only to the problems which he had already faced.

As a result there is a need for grower education on importance of birds behaviour observations and flexibility in their interpretation.

The cases of birds responses on heat stress described above are just some illustration of interaction between people, building and animals.

To improve chicken well being we use brooders. With their use we should not only save some heat energy but what is much more important to create significant temperature differentiation in a building to allow each individual bird to find the place most suitable for its thermal need which usually depends on its weight, health, appetite or just individual preferences.

Unfortunately we are not always able to create under brooder the thermal conditions which really suit birds. Sometimes we make it too hot even for the weakest birds. In response they avoid the brooders, leave the zones under them and look for place with lower temperature.

The worst happens where there is too hot under brooders and too low outside their reach. That particularly often happens with turkey poults which prefer very high temperature particularly the very first days after moving to the building. To avoid heat stress they migrate from under the brooder and end up in too cold environment. Then they to heat up themselves by huddling together which quite often leads to death by suffocation. To prevent turkey poults from leaving the brooders growers build brooder guards. They can be quite effective but only at moderate heat stress conditions. When temperature under brooder is as high as 45-50°C, chickens, trying to avoid heavy thermal stress, fight to get the best (means coldest) positions inside the brooder guard occupying it from inside. Such a strong competition among them may also lead to the deaths because of suffocation. The best solution in this case would be to lift the brooders, lower the thermostat settings or both, all depending particularly on outside climate and resistance of a building shell to uncontrolled air infiltration and heat losses.

When using tunnel ventilation we create some stable pattern of air movement and effective temperature distribution in a building.

Birds migrate looking for the better environment very well recognizing the direction where they should go. Unfortunately the best environment is available only in a small part of a building. Birds are looking for better environment which is available only for some of them. As a result they overcrowd and their environment is getting worse instead of being improved.

As a response we construct migration fence and by doing that negatively affect broilers freedom to move, one of the 5 main dimensions of animal welfare.

CONCLUSIONS

As a result of wrong management of technical systems for environment control, radiant heaters operation can result in heat stress even for a few days old chicks. To avoid heat stress under the brooder chicks migrate outside of it and loose most important benefit offered by this systems – possibility for individual birds to stay in most appropriate for them thermal environment.

There is no commercially available reliable automatic control system for brooders operation which could be left with no thorough every day birds behaviour observations accounting for the changes in their age, health status and outside climate conditions.

The efficiency of ventilation systems which reduce heat stress for adult broilers should be verified on the basis of birds behaviour response. Possible differences between various systems can be best recognized at sudden effective temperature changing (dynamic conditions) when it is relatively easy to observe the reaction of chickens as a group as well as the individual differences between animal responses.

Grower should be made conscious that all recommendations on type of ventilation and heating equipment, their positioning or thermostat settings make only some reference level which should be continuously verified by observations of birds behaviour.

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