Poultry Production: Solutions to High Temperatures in Large Poultry Sheds

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***Abstract* — Today the temperatures on the planet are very high compared to a few years ago and laying birds suffer critically from this event. Therefore, special attention should be paid to this factor when producing laying hens since stress caused by rising temperatures plays a key role in the performance of these animals. In this article three cooling systems are presented to solve the problem of high temperatures in poultry sheds. Different calculations specific parameters will be presented to obtain the correct operation of these systems. Finally, the recommended system to be used is stated according to the range of temperature and humidity of the environment.**

***Keywords*- poultry production, poultry sheds, poultry stress**

***Resumen*— Actualmente las temperaturas en el planeta son muy altas en comparación con hace unos años y las aves ponedoras sufren críticamente por este evento. Por ello, se debe prestar especial atención a este factor a la hora de producir gallinas ponedoras, ya que el estrés provocado por el aumento de las temperaturas juega un papel fundamental en el rendimiento de estos animales. En este artículo se presentan tres sistemas de refrigeración para solucionar el problema de las altas temperaturas en galpones avícolas. Se presentarán diferentes cálculos de parámetros específicos para obtener el correcto funcionamiento de estos sistemas. Finalmente, se indica el sistema recomendado a utilizar según el rango de temperatura y humedad del ambiente.**

***Palabras clave*- producción avícola, galpones avícolas, estrés avicola**

I. Introduction

In Argentina, poultry production has always been carried out in rural zones, where the birds live in large crowded sheds. On average, twenty-five thousand animals live in these facilities [1]. Also, the location of the sheds is in large fields which do not have trees to protect the birds in the shed from the sun. The effects of these two factors, rising temperatures and the number of animals in the sheds, presents producers with serious challenges which may have an impact on food production [2] since, in extreme cases, the chickens may even die.

This problem is not an issue that happens only in the local sphere but rather on a global scale as well. Food production is specifically addressed in the United Nations' 2030 Agenda for Sustainable Development within SDG 2 "Zero Hunger", more specifically through target 2.4, which aims to ensure sustainable food production and implement resilient farming practices.

There are groups of engineers who work in industry innovation, and the refrigeration of sheds for poultry is not the exception. The possible solution to the high temperatures in the sheds is the incorporation of systems with sprinklers, extractors and cellulose cells, or a system with extractors only [3]. Each of these systems needs a study prior to its installation to apply the best option in poultry houses.

The aim of this paper is to describe three options and state which the best application is depending on the climate of the area. To this end, the sizing calculations for each particular system will be developed and shown, allowing producers to calculate the type and size of system they need according to the climatic conditions. In order to fulfill this objective, this work is organized into three parts. Firstly, a description of the problem connected with poultry production and the rising levels of temperatures is explained. Next, the different solutions and the calculation for each of these are shown. Finally, the recommended system to be used is stated according to the range of temperature and humidity of the environment.

II. Optimum conditions for poultry production

Chickens are very sensitive to temperature changes, and they suffer from stress when they are exposed to high temperatures. This condition starts with temperatures higher than 25°C, and worsens as it increases. The animals use body energy reserves to maintain a thermal comfort zone. The production and growth is influenced by stress. This implies that heat stress negatively impacts the productivity and profitability of poultry production [2] For this reason, it is very important to work on this aspect to achieve the optimal breeding conditions.

There are two important aspects that affect the conditions inside the sheds: temperature and humidity. In relation to the first one, depending on the temperature, the birds present different behaviors. As illustrated in [4, Tab.1], when animals are exposed to temperatures ranging from 55-75 F there is no need for them to maintain body temperature. The ideal temperature goes from 65 to 75 F. In the 75-85F temperature range, birds decrease food consumption, egg size may be reduced and shell quality may suffer as temperatures reach the top of this range. The 85-90F range is characterized by the greater reduction in feed consumption and deterioration of the shell quality and egg size, so egg production is greatly affected. When temperatures go from 90-95F, there is a marked increment in the danger of heat exhaustion in layers and heavier birds, and feed consumption continues to decrease. In the range of 95-100 F heat exhaustion is likely to occur. To avoid this, emergency measures may be necessary, especially in terms of water provision since water consumption is high. When the temperature is higher than 100 F the survival of the birds is a concern and emergency measures will have to be more rigorous.

TABLE I

Behaviors of the range of temperatures [4]

Temperature [F]	Impact
55 - 75	Behavioral change to maintain body

	temperature
65 - 75	Ideal temperature
75 - 85	Slight reduction in feed consumption
85 - 90	Greater Reduction in food consumption
90 - 95	No food consumption
95 - 100	State of emergency
>100	Mortality risk

The second aspect that affects production is the humidity in the environment of the shed. The optimum humidity range that a chicken coop should have for better efficiency is between 60% and 80% as shown in [5, Tab. 2].

Taking into account the previous data on temperature and humidity, both variables should be considered, combined and analyzed to understand the real conditions in the poultry sheds. Adding both factors, the result must be between a specified range to provide a comfort zone. The combination of the factors is important because the shed can have a high temperature, but if the humidity is low the birds do not suffer stress, as long as the temperature does not exceed 75F. The same situation occurs when sheds present high humidity together with low temperature. The result of this combination shows a factor that has to be between 140 and 165 for optimal conditions; if the factor is lower or higher the birds suffer stress.

TABLE II
The comfort Zone [6]

Temperature [F]	Humidity [% H2O/air]	Factor	Impact
95	<45	140	Stress
95	50	145	Optimal condition
95	>70	165	Stress

III. *Possible solutions*

Currently on the market three solutions are mostly implemented to the problems of humidity and temperature in the poultry sheds. These vary in their operation and in the resources they use to lower the temperature and control the humidity.

A. Extractors and cellulose cells

The system that uses cellulose cells with extractors creates a comfortable environment in the poultry house. This system functions with the humidification of the sheds. The operation principle is the extraction of the air in one of the ends of the sheds, which produces a void in the shed and forces the air to pass through the cellulose cells. These are located at the other end of the shed as shown in [Fig 1&2,1], where the air acquires humidity, reducing the temperature in the environment. To achieve this, the water circulates across the panels; part of it evaporates in the form of humidity and the other part continues circulating in the water circuit. For this system to operate properly it is essential that the shed is airtight, except at the two ends.

Fig. 1. Cells [1]

Fig. 2. Extractors [1]

For the calculation of this system it is necessary to take into account two main aspects: the air flow and with it the water consumption. Additionally, it is necessary to know the temperature and humidity before installing the system and what the objective is in relation to these factors. This is determined considering the optimal condition for poultry production, taking into account water consumption and air flow.

1. The flow: it is recommended to have a flow that renews the air of the shed every one minute.

   V(volume of the shed): width by length by height [m³]

   F(flow of air)= V/min [m3/min]

2. The consumption of water: air circulation with a constant flow should be considered, and the appropriate mass balance of the water should be proposed.

   Data that are needed for the calculation:

   a. [T_0] → Maximum temperature
   b. H_0 → [%]Relative humidity with the maximum temperature
   c. V→[m^3] Volume of the shed
   d. C→[m^3/min] Flow of the one extractor
   e. F→[m3/min] Flow of air
   f. □ →□□□□sure
   g. ṁ□ = Flow of humidity water
   h. ṁ□ = Dry air mass flow
   i. □ = Humidity specific
   j. □ = R□□□□□□ □□□idity
   k. Ṽ = Volumetric flow
   l. ṽ = Specific volume

How are the facilities built? Considering the atmospheric pressure, a psychrometric chart is used as shown in [Fig. 3, 11]. To determine what? Knowing the temperature and humidity that the house naturally has and the desired values that must be reached, we can obtain the dry bulb and wet bulb humidity and the specific volumes.

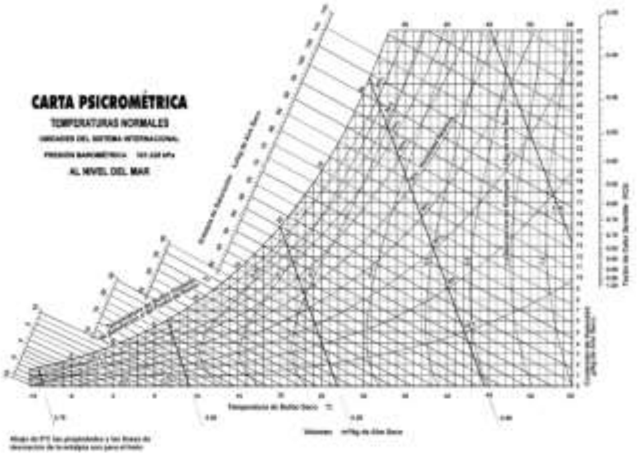

Fig. 3. Psychrometric chart [11]

$$\tilde{v}1 ; \tilde{v}1 ; \square 1 ; \square 2$$

The flow:

$$F = V * 1/\min = F[m^3/\min]$$

The number of extractors [X] is determined by:

$$X = F/C$$

The consumption of water:

$$\dot{m}\square 1 * \square 1 + \dot{m}\square = \dot{m}\square 2 * \square 2$$

$$\dot{m}\square\square = \dot{m}\square\square = \dot{m}\square = \square\square\square$$

$$\dot{m}\square = \frac{\square}{\tilde{v}\,2}$$

$$\dot{m}\square = \dot{m}\square * (\square\square - \square\square)$$

The ṁ□ is the water consumption per minute. To know the water consumption per day, the producer must multiply ṁ□ by the number of minutes that the system will require in operation [11].

B. Sprinklers

The use of sprinklers, as shown in [Fig. 4, 8], to reduce the temperature in the poultry house is based on individual sprinklers that apply water over birds. This system also has some fans that produce circulation of the air together with the water, provoking a wind-chill effect that bluffs chickens into thinking the chicken house is cooler than it really is. This helps because the problems in the birds are caused by stress and if this makes the birds cooler, they will not be stressed [7].

Fig. 4. Sprinklers [8]

As an example, a system made for cows will be presented in this work. For practical purposes, the system is the same for any type of animal.

For the correct operation of the system, it is important to know that it must be put into operation for a short period of time (30[s] to 180[s]) applying a flow rate of 0.0254[m^3/s]. This will allow the birds to get properly wet.

As previously stated, this system has fans that allow air to circulate inside the shed, which is why after spraying, they must be turned on immediately, bearing in mind that they must work continuously after the previous cycle. If higher precision is needed, it is recommended to visit places where they have an evaporator cooling system in operation [12]. This will help to get an idea about such systems and how they work in already productive places.

Taking into account the previous suggestions and that the air changes are 20 times per hour for this system, the water consumption and the fan flow rate can be calculated as follows [13].

Data that are need for the calculation:

a. V→[m^3] Volume of the shed
b. C→[m^3/min] Flow of the one extractor
c. F→[m3/min] Flow of air
d. ṁ□ = Flow of humidity water
e. ṁ□ = Dry air mass flow
f. □ = Humidity specific

The flow:

$$F = V * 0.33/\min = F[m^3/\min]$$

The number of extractors [X] is determined by:

$$X = F/C$$

The consume of water:

$$\dot{m}\square 1 * \square 1 + \dot{m}\square = \dot{m}\square 2 * \square 2$$

$$\dot{m}\square\square = \dot{m}\square\square = \dot{m}\square = \square\square\square$$

$$\dot{m}\square = \frac{\square}{\tilde{v}\,2}$$

$$\dot{m}\square = \dot{m}\square * (\square\square - \square\square)$$

The ṁ□ is the water consumption per minute. In order to know the water consumption per day, the producer must multiply ṁ□ by the number of minutes that the system will require in operation [11].

C. Extractors only

The extractors, as shown in [Fig. 5, 1], are used to ventilate the environment. The objective is to renew the air enclosed in the sheds and to take it out to the outside. Also, this system reduces the temperature of the sheds and creates a zone of greater comfort for the hens.

Fig. 5. Extractors only [1]

For the calculation of this system it is necessary to take into account the renovation of air necessary for each place. This variable is between 6 - 10 per hour [9]. The following points should be taken into account:

a. V→[m^3] Volume of the shed
b. C→[V/h] Renovation of air
c. R→[m^3/h] Renovation of air per hour
d. Ve→[m/h]Airspeed in worst condition
e. I→[m^2]Air inlet opening
f. Q→[m^3/h]Fan air flow
g. Cv→Number of fans
h. Ci→[m^3/h]Openings minimum flow

Having the volume of the shed, the necessary renovations can be found, multiplying the volume by the regulatory renovations. The resulting previous data must be divided by the volume of air that the manufacturer of the fan provides when purchasing it, resulting in the number of fans needed [10].

Next, a development of formulas will be made to carry out the system:

$$R = V * C[m^3/h]$$

$$Ci = Ve * I[m^3/h]$$

$$Cv = R/Q$$

IV. *Solutions according to the needs of the poultry*

As has been discussed throughout the development of the work, poultry is affected to a different extent depending on the ranges of temperature and humidity to which they are exposed. Next, a summary is presented with specifications for the refrigeration system to use according to the range of temperature and humidity.

Three temperature ranges will be provided to recommend the solutions. These are accompanied by the percentage of existing humidity in the environment since it must be considered to calculate the factor that takes into account the temperature and humidity as a whole and that defines the level of comfort that the birds have.

A. Little difference in temperature and low percentages of humidity

For a little range of temperature difference it is recommended to apply a system that uses only extractors. This type of refrigeration system reduces the thermal sensation in the sheds, but this is only true when the temperature of the environment does not widely exceed the critical stress temperature of birds. In the event that the temperature exceeds the critical values, it is necessary to use another method of air conditioning.

B. Average temperature difference and intermediate humidity percentages

As for a medium range of temperature difference, it is recommended to apply a system that uses sprinklers. This type of cooling system reduces the thermal sensation of the birds inside the house. It is necessary to clarify that this system does not improve air quality, but rather gives the birds a feeling of comfort. It is not recommended for high humidity areas because this system introduces humidity and the sum of both can generate condensation in the soil, giving rise to a "swampy" environment which can generate different diseases due to excess exposure to wet soil.

C. Large temperature difference and large percentages of humidity

The more effective system for reducing large temperature differences is the system that includes extractors and cellulose cells. This allows the temperature to be lowered whenever there is low humidity in the environment before turning on the system. This is possible in times of high temperatures, because the sun that heats the environment also dries it. Being an environment with low humidity allows the incorporation of humidity to it.The biggest advantage of this system is that it creates a real comfortable space for the birds, and not just a sensation, thus reducing stress and increasing production in the most extreme conditions.

V. Conclusion

As we know today, temperatures on the planet are very high compared to a few decades ago and laying birds suffer critically from this event. Therefore, special attention should be paid to this factor when producing laying hens. We also know that the stress caused by the increase in temperature plays a fundamental role in the performance of these animals.

As for the solutions, this paper has proposed three: extractors and cellulose cells, sprinklers and extractors only. The performance of these systems will depend on the temperature and humidity that prevails in the region where they are installed. Taking into account these data and also the data of the optimal conditions for the laying hens, the necessary calculations to determine the dimensions of the facilities for optimal operation and higher production efficiency within the sheds have been introduced. It is expected that poultry producers can take advantage of these data to make informed decisions at the moment of deciding on the best system for the area where the shed is located.

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