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Numerical modeling of artificial egg incubator efficiency

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Abstract*— *In summary, this work presented the essential points enabling the process of operating the artificial incubator, having sought to establish the link between theory and reality, the experimental phase was tackled. This involved manipulating the prototype artificial incubator materialized in the mechanical workshop of the Institut Supérieur de Techniques Appliquées de Kinshasa. The Matlab software was used to run simulations which produced results showing the variation in egg hatching rate as a function of temperature, the variation in internal temperature as a function of the incubator's external temperature, and the variation in humidity as a function of time (days). The results found were discussed with those found by other researchers.

I. INTRODUCTION

Thanks to its nutritional properties, chicken meat is becoming a necessary commodity for humans and many other living species. To obtain it in a renewable way, we resort to the production of chicks, an operation that requires the presence of a broody hen. Increased consumption of chicken meat is proving insufficient to meet the needs of the entire population, as it is difficult for a hen to incubate more than a hundred eggs in a day. To maximize chick production, scientific investigations are in full swing and technologies are being developed to make the process of profitability easier. To this end, researchers have produced the so-called artificial egg incubator, at device designed to hatch eggs under at synthetic influence that approximates natural incubation. A number of studies have shown that the choice between a natural and an artificial incubator depends on the number of chicks the user intends to raise at the same time, the work involved, the operating costs of an incubator, and the results and quality of the incubation products [1]. With this in mind, we turned our attention to numerical modeling of the efficiency of artificial egg incubators. Since the artificial incubator allows the hatching of a quantity of eggs laid, it facilitates the production of a high rate of chicks that are viable at the lowest cost. The efficiency of an incubator is based on its ability to regulate heat, humidity, ventilation and egg rotation to ensure normal embryonic development [2]. While the materialization of these skills can only take place if there is optimization of the variation of the egg hatching rate as a function of temperature, variation of the internal temperature of the function, of the external temperature of the incubator, of the variation of humidity as a function of time. We therefore decided to carry out this study with the aim of determining the efficiency of the artificial incubator before the egg is introduced into it.

II. MATERIALS AND METHODS

The methodological approach consisted in analyzing concrete situations, and obtaining information from various groups of people and documents containing useful information on the subject. This led us to visit the DAIPN farm in Kinshasa and to handle the prototype artificial incubator produced in the mechanical workshop of the Institut Supérieur de Techniques Appliquées in Kinshasa. We also consulted documents containing information relating to our object of study. For the simulation, we used Matrix Laboratory (MatLab) software.

III. INCUBATOR OPERATING PROCESSES

3.1 Egg processing

To achieve efficient and profitable operation of the incubator, the following steps must be taken into account:

- Egg selection;
- Egg cleaning;
- Storage;
- Incubation [3], [4].

3.1.1. Egg selection

To make a good selection, you need to know that egg weights are not identical. It varies from breed to breed, from thirty to seventy grams. The best results are obtained with eggs from good layers of normal size. These eggs must be fertilized before being placed in the incubator for incubation. A rooster can fertilize several hens. Effective results are obtained with one cock for every ten hens, but for heavy breeds, the number of hens must be reduced. After mating, the hen lays the fertilized eggs for at least eight days.

The shape of the egg must be taken into account, as a malformed egg is not suitable for incubation if good results are to be achieved. The quality of the shell itself is very important for good selection. If the shell is cracked, the egg is dehydrated. If the egg is dehydrated, it produces a stillborn or very weak chick.

3.1.2. Egg cleaning

The choice of eggs is a crucial step in the incubation process. After selecting clean, well-shaped eggs, they are cleaned using a clean, dry cloth. This is a very dextrous process, given that the egg is a very fragile body, liable to break at any moment.

The eggshell is porous, allowing dirt, bacteria, water and air - the list goes on. Hence the need to avoid using water to clean eggs, as it opens the pores in the shell, weakening incubation results. Water is not the only solution to avoid if you want to produce chicks of the right quality. If a solution is used to remove dirt, it will not only remove the dirt but also the outer cuticle of the egg, exposing it to bacteriological contamination. But if we're dealing with very dirty eggs, they should be brushed in water at a temperature higher than that of the egg (40°C). A disinfectant such as sodium hypochlorite ($NaClO$) can be added to get rid of pathogenic germs.

Eggs should be collected using a non-porous or easily-cleaned plastic tray, to avoid contamination or transmission of bacteria.

3.1.3. Egg storage

Once eggs have been collected and cleaned, the question remains as to where they should be placed for storage while awaiting incubation. It is advisable to place selected and cleaned eggs in at cool place at room temperature. Eggs destined for incubation should be collected and placed under cover as soon as possible. The ideal temperature for storing eggs is 25°C and the ideal relative humidity is 75%. High humidity is evidenced by the appearance of microscopic fungi called molds, which form branched vegetations on the surface of organic matter. Mouldy eggs should be discarded and not used for incubation. Most species tolerate at 14-day storage period before the hatching rate is affected. During this stage, egg turning is also essential for a high hatching rate.

3.1.4 Egg incubation

Egg incubation is the final and crucial step in determining whether the previous steps have been carried out correctly. It is after this stage that we will obtain the desired results or not. To achieve favorable results, a few parameters must be respected. The parameters determining results are: temperature; humidity; ventilation; egg turning; egg candling. As a result, the following boundary conditions need to be determined:

4. Numerical simulation

We carried out the numerical simulation using the data below, representing the above-mentioned boundary condition, implemented by running the program in Matlab software.

Data to be simulated

- Variation in temperature inside the incubator: 0 to 45°C;
- Temperature variation outside the incubator: 0 to 60°C;
- Variation in humidity inside the incubator: 0 to 80%;
- Variation in egg hatching rate: 0 to 100%;
- Variation in incubation time: 0 to 30 days.

IV. RESULTS AND INTERPRETATION

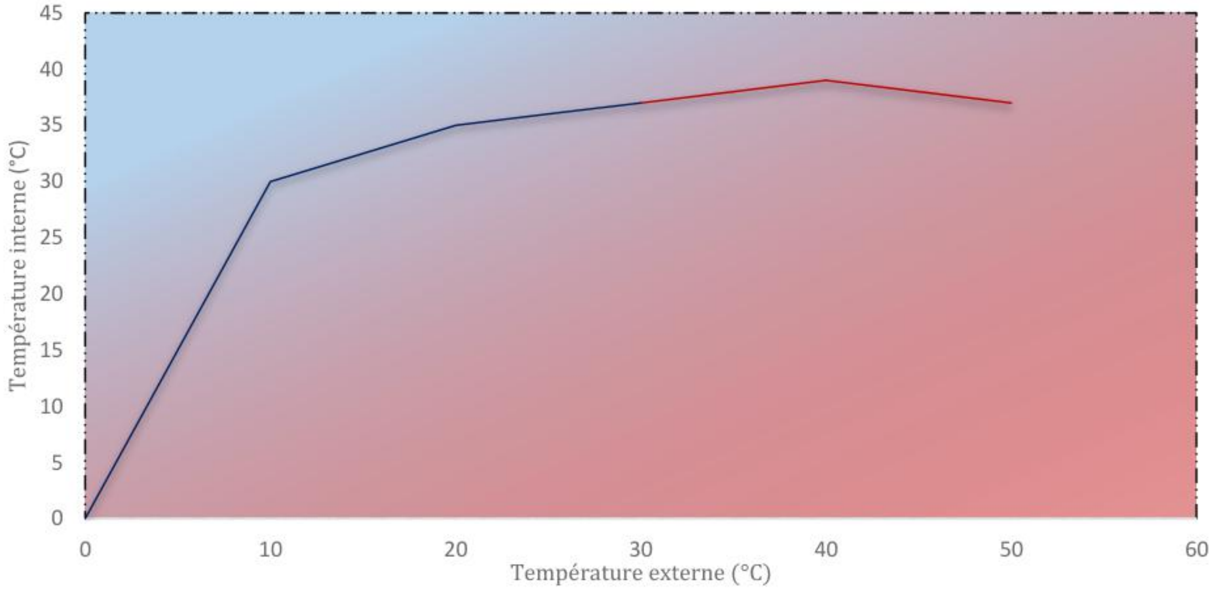

Fig.1: Variation in internal temperature as a function of external temperature.

Figure 1 shows the variation in internal temperature as a function of the incubator's external temperature. The internal temperature rises from 0 to 40°C, while the external temperature rises from 0 to 50°C. This proves that our incubator is working properly.

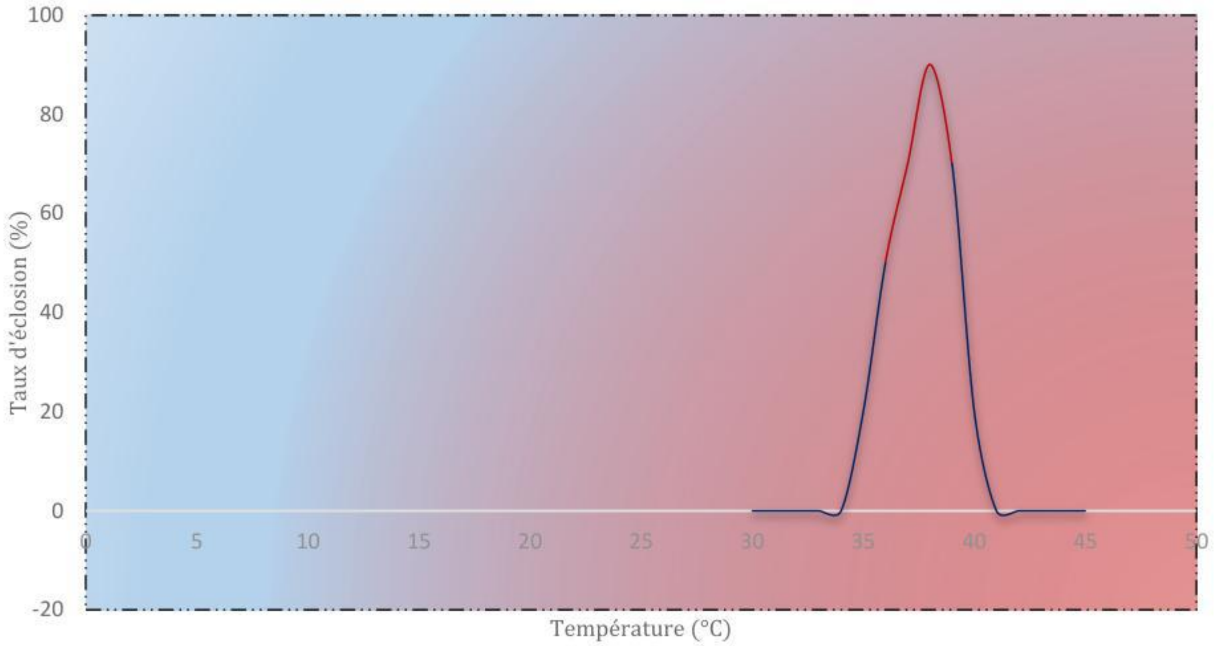

Fig.2: Variation in egg hatch rate as a function of temperature

Figure 2 illustrates the variation in egg hatching rate as a function of temperature. It can be seen that the hatching rate varied from 0 to 90%. While the temperature varied from 30 to 45°C. This variation in the curve attests to the reliability of our incubator.

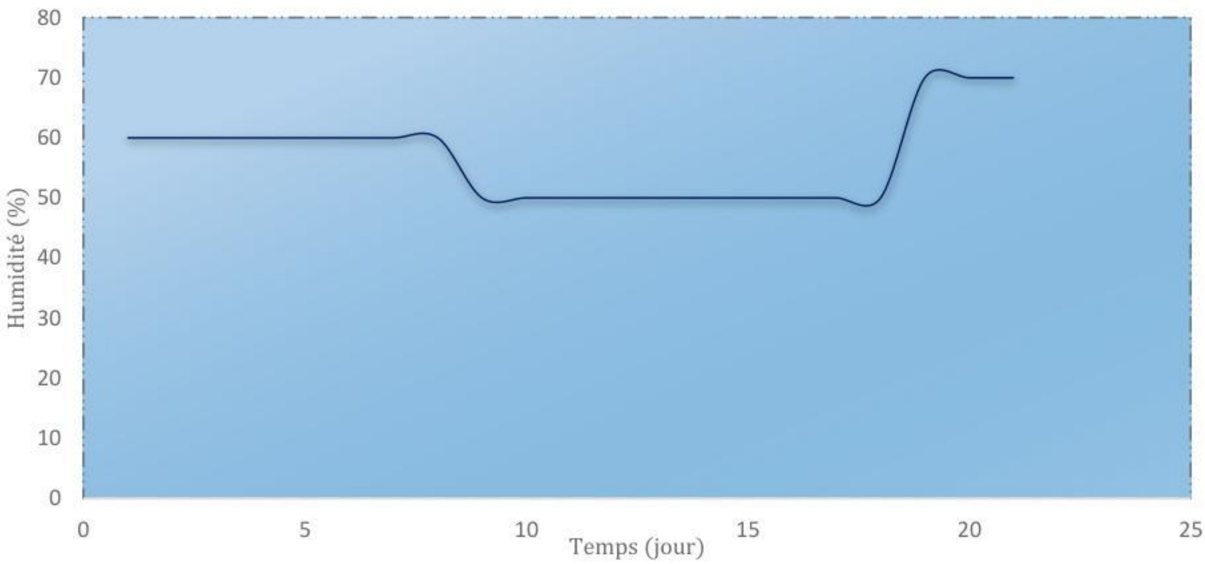

Fig.3: Humidity variation as a function of time.

Figure 3 shows how humidity varies with time. It can be seen that when the eggs hatch, the incubator does not maintain the same percentage of humidity, because at each stage, the incubated eggs need a well-defined degree of humidity. In order to achieve satisfactory results, compliance with the required humidity level for incubated eggs during hatching is more than a requirement. It should be noted that during the first week of incubation, the required relative humidity is 60%, at the beginning of the third week, the relative humidity is 50% and a few days later, i.e. before hatching, the humidity level needs to vary to 70%. From day 19, eggs can be gently moistened with a damp cotton cloth to soften the shell and help the chicks to hatch.

V. DISCUSSION

This study produced results defining the variation of internal temperature as a function of external temperature, ranging from 0 to 40°C for internal temperature and 0 to 50% for external temperature. In this respect, at number of research studies point out that if the outside temperature is below 30°C, the incubator will have to work hard to provide an adequate temperature for the incubated eggs. But if the outside temperature is above 40°C, the incubator will work to maintain the inside temperature at a range of 37 to 39°C, confirming the efficiency of our incubator [5],[6].

With regard to the variation in egg hatch rate as a function of temperature, the variation ranged from 0 to 90% for hatch rate and from 30 to 45°C for temperature. Comparing our results with those reported by Wageningen et al, Pelé, Eekeren et al, Azeroul [7],[8] [9],[10] who report that the hatching rate in an incubator can vary from 50 to 70%, 70 to 90%, 65 to 70% and 87%. It is worth noting that our incubator's hatching rate is close to those of PELE B. and AZEROULE. In addition to these findings, there are those of WAGENINGEN et al and EEKEREN N.V et al. which fall within the range of our incubator hatching rate results. As for incubator temperature, the variation is from 30 to 45°C. ELBACHIR MOHAMMED et al [11] found that at temperatures below 35°C to above 40°C, the hatching rate was zero. A good percentage of hatchings occur in the 37°C to 39°C temperature range. On the same subject, MUKHTAR IBRAHIM B. et al [12] point out that incubation temperature variation curves on day 1 and day 10 remain very similar and uniform, with the following respective minimum and maximum values: day 1 (37 to 40°C and 37 to 78°C) and day 10 (37 to 45°C and 37 to 73°C). With the same daily average ranging from 37 to 59°C. Tackling this question with the same logic as MUKHTAR IBRAHIM B. et al. after analysis we find that the average of our temperature results is 37°C. This proves the reliability of our incubator. As for humidity variation with time (Days), the required humidity is 60% at the beginning of the third week, relative humidity varies from 50% to a few days before hatching, humidity varies once again to 70% at day 19. This is why SUSMITA M. et al [13], SHAYMAA A. et al [14], maintain that relative humidity in the incubator and in the ambient environment varies respectively from 54 to 56% and from 70 to 76%, with averages of 55.08 to 71.2%. These values are acceptable for proper incubator operation. Looking at our humidity values, we find that they are within the range of those found by the above-mentioned researchers.

VI. CONCLUSION

Here we are at the end of this work, which has shown just how essential the development of innovative technologies in poultry farming is to optimize the breeding and rearing process. We have highlighted the operating process of the artificial incubator, which requires eggs to be processed through selection, cleaning, conservation and incubation. To scientifically prove the efficiency of our artificial incubator, a boundary condition was established, whereby the results determining the variation of egg hatching rate as a function of temperature, the variation of internal temperature as a function of external incubator temperature, Variation of humidity as a function of time. This set of results attests to the cost-effectiveness of our artificial incubator model.

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