Introduction

Poultry farming in Algeria has transitioned from family-based production to a more advanced and organized industrial production (Kaci & Boukella, 2007). This has been made possible by the precise management of technical and hygienic breeding standards, alongside careful handling of the eggs that are to be hatched. However, the industry is currently experiencing considerable underperformance, which is impacting both profitability and production quality. This is largely due to microbial contamination of breeding animals, as well as changes in egg characteristics. Simultaneously, there could be a decline in cock fertility, and there may be high embryonic mortality during hatching, as noted by Mpupu et al. (2019). Pathogens can be transmitted through the egg or by contaminating its surface (Dana & Daoudji, 2019). Poultry is still afflicted by major diseases, especially salmonellosis and colibacillosis, which are the primary reasons for poultry mortality (Allaoui et al., 2017; Ghafrir et al., 2008). These diseases cause economic losses exceeding 40% (Hakkari, 2011), despite the implementation of prophylactic measures. The primary objective of our study is to collect pertinent data on the breeding habitat, egg incubation, and hatching processes within the hatchery. Additionally, we aim to assess the level of bacterial contamination present on various surfaces including litter, incubators, building walls, feeders, drinkers, and ambient air quality. The study investigated the presence of highly concerning bacteria, including enterobacteria (specifically Salmonella spp.), fecal coliforms (specifically Escherichia coli), Pseudomonas aeruginosa (identified by pyoverdine), and staphylococci (identified by Staphylococcus aureus) within breeding center environments.

Materials and Methods

The experiment took place over a 5-month period in 2018 at three extensive poultry farms within the meat sector, which, for the purpose of the study, we call the breeding center, the production center, and the hatchery, situated in the Mostaganem region in northwest Algeria. Based on the gathered data, flock number 35, comprising 3346 birds aged 19 weeks, is housed in six buildings at the breeding center. The production center consists of two batches, with each batch comprising roosters and pullets accommodated in three buildings. In the initial batch, there are 17,467 birds aged 46 weeks, while the subsequent batch consists of 16,679 birds aged 44 weeks.

As per ISA (2005), the rearing duration spans from sexual maturity to slaughter. The hatchery for broiler birds comprises an egg reception area, along with a preheating and storage space. It is equipped to combat harmful germs is crucial to enhance animal health and farm profitability. The objective of this study was to objectively examine the detrimental impact that airborne and surface-dwelling bacteria, including Salmonella spp., Escherichia coli, Staphylococcus aureus, and Pseudomonas aeruginosa, on breeder survival, egg-laying rates, and overall hatchability of eggs within hatcheries. A total of 184 samples were procured from three poultry breeding centers in the meat industry sector located in the Mostaganem region in Algeria. The breeding center saw a cumulative mortality rate of 7.1% according to the study. The reduction in production was linked to a decrease in cumulative hatching egg production (604 137 ± 0.01 for batch 1 and 601 767 ± 0.01 for batch 2), as well as a significant decline of 13.70% in the hatching rate, which can be attributed to the circulation of pathogenic germs that impacted the birds' viability. The contamination has been associated with the decay of litter housed inside the buildings, elevated levels of ammonia, eggs that have been polluted with droppings from birds housed on the floor, and improper disposal of dead birds. To produce high-yielding broiler chicks, it is paramount to maintain sanitary, hygienic, and technical standards, alongside careful handling of the eggs that are to be hatched.

Keywords: Egg-laying percentage, hatching rate, meat sector, poultry farming, yield
with 18 incubators, 3 hatcheries, each with a capacity of up to 50,400 eggs, and an area to sort, vaccinate, and dispatch chicks.

**Sampling**

One hundred eighty-four air and surface samples were collected from three meat poultry rearing centers in the Mostaganem region (Algeria): 65 samples from the rearing center, 70 samples from the production center, and 49 samples from the hatchery. In order to sample the ambient air, petri dishes containing selective culture media for each targeted germ were opened for 10 minutes according to Jean-Paul, (2012) methodology. The media employed are as follows: *Salmonella*–*Shigella* agar, violet red bile glucose agar, King B agar, and Chapman’s agar are used for detecting *Salmonella* spp., *E. coli*, *P. aeruginosa*, and staphylococci, respectively. Four plates of each medium are placed in different locations within each building.

For surface testing, samples are obtained using the swabbing technique, in which a swab is rubbed against the surface being tested. The swab is placed into a test tube with 5 mL of nutrient broth, following JORA (2004). Isolated samples are then transported to the laboratory and processed within the same day.

Once in the laboratory, the isolated colonies are incubated at 37°C and examined macroscopically, considering size and shape. The strains are purified using the streak method, examined under a microscope and characterized biochemically using the classical gallery.

Suspected strains of *Salmonella* spp. undergo rapid slide agglutination tests utilizing mixed anti-O somatic sera, monovalent anti-O9 serum tests, and anti-H flagellar serum tests (GM): composition of polyvalent and monovalent sera.

**Results and Discussion**

**Breeding Center Physical Analysis**

According to the manager of the center, the received group of chicks adhered to the guidelines outlined in Hubbard Technical Guide (Hubbard F15, 2015) regarding hygiene practices and disease prevention protocols (including following the specified dimensions of crawl space, disinfectant spraying and fumigation, and vaccination). The center recorded a 1.25% and 1.29% total mortality rate during the first and second weeks, respectively (Figure 1). This could be attributed to different factors that the batch of chicks may have encountered from hatching to placement, such as vaccination and transit. These measures unavoidably affect the physical health of the chicks and pose a potential hazard of microbial contamination in the hatchery (Diaf, 2010). In reality, newly hatched chicks possess an undeveloped immune system, leaving them susceptible to swift colonization by various commensal and pathogenic microorganisms during the initial days of life (Humbert & Salvat, 1997).

Despite decreased mortality rates between week 3 and week 14, a notable surge in mortality rates took place during week 15, reaching a peak at week 17. The mortality rate for building 5 was 2.43%.

At 19 weeks of age, the chickens had an overall mortality rate of 7.1%, as shown in Table 1. The litter appeared deteriorated, damp, and piled around the troughs, with the rest of the surface covered in dust. Bradbury and Kleven (2008) have suggested that such conditions create a favorable environment for the development of microorganisms and insects, as confirmed by Lallemand Animal Nutrition (2023). These insects could act as intermediaries for pathogens and hosts for cestode parasites. We observed exceptionally high levels of ammonia in buildings 3 and 6, as well as cases of lameness and leg paralysis. The animals affected were left nailed to the floor and disheveled when they were transferred to the production center.

Removal of poultry corpses is carried out once a week, according to the center manager. Chickens present a risk of contamination due to their contact with healthy subjects and the use of litter. Shivaprasad (2016) showed that birds aged between 7 and 12 weeks frequently develop arthritis and synovitis due to *S. aureus*. Research by Aubrey-Roces et al. (2001) indicates that rats and mice gnaw and soil left-over materials, rendering them unfit for consumption. They serve as a medium for the elimination of bacteria, in particular *Salmonella* spp. as shown by Davies and Breslin (2003) and *E. coli* as indicated by Rachidi-Sidhoum and Brugere-Picoux (1992).

**Bacteriological Analyses**

Sixty-five samples of air and surfaces from the breeding center were analyzed. The analysis of the air samples, which included

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**Table 1.**

<table>
<thead>
<tr>
<th>Buildings</th>
<th>Number of Staff at Start-Up</th>
<th>Cumulative Number of Mortality</th>
<th>Cumulative Mortality Rate %</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAT 1</td>
<td>5929</td>
<td>408</td>
<td>6.88</td>
</tr>
<tr>
<td>BAT 2</td>
<td>5817</td>
<td>387</td>
<td>6.65</td>
</tr>
<tr>
<td>BAT 3</td>
<td>5921</td>
<td>447</td>
<td>7.55</td>
</tr>
<tr>
<td>BAT 4</td>
<td>5870</td>
<td>359</td>
<td>6.12</td>
</tr>
<tr>
<td>BAT 5</td>
<td>4864</td>
<td>476</td>
<td>7.32</td>
</tr>
<tr>
<td>BAT 6</td>
<td>6542</td>
<td>521</td>
<td>7.96</td>
</tr>
<tr>
<td>TOTAL</td>
<td>36580</td>
<td>2598</td>
<td>7.10</td>
</tr>
</tbody>
</table>

*Note: BAT, building.*
macroscopic and microscopic examinations and biochemical tests (data not shown), demonstrated contamination by the germs under investigation, with the exception of *Salmonella*, which could not be isolated. This contamination is directly linked to the high level of dust that is present within the buildings and which is directly related to the density of the animals (data not shown). This dust primarily results from the beddings disturbance caused by animal activity. Dust may carry pathogens, as stated by Diaf (2010) and Lallemand Animal Nutrition (2023).

The findings, ascertained through macroscopic, microscopic analyses, and biochemical tests (data not presented), indicate that the bedding is the primary source of contamination, followed by the dusty walls of the buildings (which explicate the microbial load), and then the feed and drinking troughs (data not presented). Sauter et al. (1981) have reported similar results. Dust and ammonia concentrations are correlated with microbial levels (ITAVI, 2012).

**Production Center Physical Analysis**

The egg-laying curves were compared to a theoretical curve proposed by the supplier of the HUBBARD F15 strain (www.Hubbarddbreeders.com).

In batch 1 (Figure 2), the laying of eggs by female breeders began slowly with a weekly production of 270 ± 1.35. However, in weeks 26 and 27, the actual curve deviated from the theoretical curve, resulting in a weekly production difference of 6.79% and 9.16%, i.e., a hatching egg production of 18,093.66 ± 0.17 and 28,289 ± 0.09, respectively. The center manager attributed this to the males’ early sexual maturity, causing the deviation.

According to ISASA (2005), early sexual maturity is a desirable trait resulting from optimum synchronization of male bodyweight and favorable start-up conditions involving a prescribed lighting program and feed. This enables hens to enter production at an earlier stage. Furthermore, the cumulative mortality rate of 0.66% for males and 0.30% for females observed at 46 weeks of age is expected and typical for the current period. However, batch 1, with a sex ratio of 0.13, has exhibited inconsistent male mortality rates since relocation to the center, reaching its peak at 1.09% at 29 weeks of age.

Incubating eggs from pullets aged 26 weeks yielded a hatching rate of 80.26%. The highest hatching rate (89.83%) was observed for eggs obtained from 36-week-old pullets, while for eggs from 47-week-old pullets, the rate decreased to 64.78%. This decline was attributed to egg explosions in incubators and brooders, the incidence of rotten and clear eggs, and embryonic mortality. These factors indicate the presence of one or more pathogens in the hatchery, despite adherence to hygrometry and temperature conditions.

In batch 2, the egg-laying curve began shortly before and then deviated from the theoretical curve without reaching its peak. Moreover, the curve remained below the theoretical curve for most of the laying period (Figure 3).

Female breeders aged between 2 and 48 weeks had an average mortality rate of 0.74%, while males had a mortality rate of 1%. At 48 weeks of age, the cumulative quantity of hatching eggs produced was 582,592.667 ± 0.01, equivalent to 76.66 hatching eggs per starter hen compared with the 113.54 eggs expected according to the strain guide (Hubbard F15).

This difference is attributed to the loss of production due to laying collapse episodes. Several drops were observed during the production period. The first drop occurred between weeks 30 and 33, with a rate of 4.13%. Subsequent drops were recorded in weeks 35–36, 38–39, 42–44, and 46–48, with rates of 0.71%, 0.86%, 5.56%, and 1.23% respectively, compared to the theoretical laying curve.

The recurring falls suggest an infectious hypothesis, as they appear repeatedly. In fact, at the 48-week mark, the center observed a considerable decline in egg production (49.61%), with an average production rate 7.01% lower than expected. This indicates the spread of a pathogenic agent in waves. However, as these breeders were all vaccinated against Newcastle disease, infectious bronchitis, and Gumboro during the rearing phase and received curative antibiotic and vitamin therapy, which, in most cases, led to a decrease in the proportion of affected individuals, we cannot exclude the possibility of an attenuation of clinical signs resulting from infection by a specific pathogen (Gupta et al., 2014).

The hypothesis of a major technical cause, such as a lighting failure, intense stress, or interruptions in the feed supply, should be considered in the event of a sudden short-term drop in egg production, as this can lead to significant losses, which explains the recovery of the curve in the following week once the problem in question has been resolved. This theory is supported by the results of Lagoutte (2010).

Eggs remain unincubated until 26 weeks due to their small size, which results in small chicks that die post hatch. The recorded hatching rates demonstrate repeated disturbances. Batch 2 began with the same rate as batch 1 (80.26%). The first decline was recorded at 33 weeks of age, with a rate of 75.80%. The curve later recovered to a maximum of 86.30% at 38 weeks of age, but fell sharply to 64.78% at 45 weeks of age. The reasons behind batch 2’s subpar

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**Figure 2.** The overall performance of the breeding pullets in batch 1.

**Figure 3.** Overall performance of lot 2.
performance align with those of batch 1, as they originated from the same center and were incubated together.

Bacteriological Analysis
The results of 70 air and surface samples taken from the buildings of the two batches and the storage room (Table 2) were analyzed macroscopically and microscopically (Figure 4). Subsequently, the targeted germs were identified through conventional biochemical identification methods (data not shown).

Bacteriological (Figure 4) and biochemical analyses of the air (data not shown) reveal a considerable degree of contamination, with significant quantities of *S. aureus* and coliforms. This microbial load is likely to contaminate eggs in incubators and chicks after hatching. The causes of this contamination can be attributed to the quality of the litter, the presence of used bulbs, rodents, tapeworms, flies, and the accumulation of uncollected chicken corpses, all of which contribute to microbial growth (Payot, 2019).

In addition, the dwellings and farms scattered around the area, which use the droppings from former chicken flocks as fertilizer, add to the emissions of harmful microorganisms. During wet periods, the risk of ecological pollution from agricultural products is exacerbated by runoff from farms and fields where manure is spread, as demonstrated by Blaustein et al. (2016). Wild birds and feral dogs and cats in the area may also be potential sources of contamination, according to Duchateau (2019). However, surface contamination was most significant on livestock units, building walls, feed troughs, and finally water troughs (data not shown).

The significant presence of *Enterobacteriaceae* on surfaces increases the possibility of contamination of the following batch by *Salmonella* spp., despite the negative results of *Salmonella* spp. tests carried out on the sampled surfaces, which remain minute in relation to the total surface area. It is clear that a nonsusceptible animal can carry and excrete infectious agents without showing clinical signs (Manis, 2020).

Hatchery
A total of 49 samples were isolated from different parts of the hatchery. The samples were then examined to identify the pathogens of interest. After identification by macroscopic and microscopic examination and confirmation by biochemical identification (data not shown), the suspected *Salmonella* spp. were subjected to rapid agglutination tests on slides using the appropriate sera (Figure 5).

It should be noted that the hatchery is close to homes, farms, livestock farms, and a main road, which increases the risk of airborne transmission of the germ. Uncleared areas (nearby trees and grass) retain contaminating dust and serve as nesting sites for insects and birds. There is also a significant presence of cats, which are likely to be vectors, as reported by several authors (Ribbens et al., 2008).

Hatching eggs stacked in trays in the storage room are surface disinfected by fogging, as the product does not systematically reach all

### Table 2.

**Presence or Absence of Germs Sought in the Premises Concerned**

<table>
<thead>
<tr>
<th>Culture Medium</th>
<th>SS</th>
<th>VRBG</th>
<th>King B</th>
<th>Chapman</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling site</td>
<td>Air</td>
<td>Surface</td>
<td>Air</td>
<td>Surface</td>
</tr>
<tr>
<td>Storage room</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>LOT 1</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>LOT 2</td>
<td>++</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
</tr>
</tbody>
</table>

*Note:* −, refers to absent; +, refers to present; SS, Salmonella – Shigella; VRBG, Violet Red Bile Glucose.

**Figure 4.**

*Phenotypic examination of the germs sought.* *E. coli*, *Escherichia coli.*

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**Macroscopic observations**
the eggs, and therefore germs present on shells soiled by feces from laying on the ground can penetrate through the pores of the shells in the first few hours after laying, with the risk of contaminating the equipment and the air inside the machines and premises (Puterflam & Goater, 2007).

Although the hatchery environment is sprayed with TH5 or BESTOP disinfectant sprays or fumigated with SteriFum, this does not reduce the level of contamination, especially internal contamination, because disinfection is not carried out correctly on the farms. Furthermore, candling in hatcheries is still not practiced, although it is an important step in eliminating clear, microcracked eggs, a source of bacteriological contamination according to the hatchery health quality charter. It has also been noted that the forward march, which is a guarantee of durability and additional contamination, is not respect.

**Bacteriological Analyses**

The results of the bacteriological control of the environment and surfaces in the hatchery show the following points:

- Hatchery numbers 1 and 2 showed the highest level of contamination, despite the disinfection recommended by the module manager prior to installation.

We observed a high concentration of *E. coli* in all our samples, namely the egg reception room, incubator number 1, hatchery numbers 1 and 2, and the sorting and dispatch room.

According to Souillard et al. (2019), *E. coli* is the germ most associated with yolk sac and omphalitis infections (74%), and mainly with in-shell mortality and even chick mortality, or genital infections with ovariitis in layers (Nolan et al., 2013).

A significant concentration of *S. aureus* was also isolated in all centers. This is a ubiquitous germ that is strongly associated with omphalitis and infection of the yolk sac and liver of chicks that succumb during the first week (Souillard et al., 2019).

The high frequency of egg explosions in hatcheries is due to *P. aeruginosa*, which can lead to airborne contamination of hatched chicks, point out (Rachidi-Sidhoum & Brugere-Picoux, 1992).

*Salmonella* spp. have also been isolated in hatcheries 1 and 2 and in the chick sorting and dispatch room, which explains the sharp drop in the hatching rate of 13.70%. According to the information gathered, the hatchery had already experienced a wave of salmonellosis (serovar Dublin) last February. The fall in the hatching rate is accompanied by a drop in egg fertility, which explains the high number of putrefied eggs.

Chicks that escape this fate at the hatchery may die on the farm after a week and may constitute a major risk factor for contamination of farm buildings by their droppings.

**Conclusion**

This study has at least allowed us to gain a better understanding of the overall laying curves, which show considerable variability around the decline in laying. This variability in the physical flow can be linked to the geographical location of the farms, the hygiene and health plans in place, the management of mortalities, the presence of wild animals in the vicinity, and the failure to follow the forward march. The two main problems associated with this variability are, on the one hand, the difficulty of assessing the economic consequences of laying failures and, on the other hand, the difficulty of identifying the probable causes of these failures. In fact, the microbial contamination of the air and surfaces throughout the chain revealed by our observations clearly indicates the presence of zoonotic germs (*Salmonella*) in the hatchery and pathogenic and/or opportunistic avian germs (*E. coli–Staphylococcus–P. aeruginosa*) from the farm to the hatchery. The microbial load was high according to the results of phenotypic and biochemical analyses of samples taken from surfaces. The air showed a relatively high level of contamination, as evidenced by the presence of staphylococci, Enterobacteriaceae, and *Pseudomonas* isolated from the different links in the chain. This microbial concentration was directly related to the level of dust and the concentration of ammonia. Bacteria that contaminate the air and surfaces are deposited on the eggs.

**Ethics Committee Approval:** All experiments were carried out in accordance with the guidelines of the Algerian Association of Experimental Animal Sciences (agreement number 45/DGLPAG/DVA.SDA.14).

**Informed Consent:** Written informed consent was obtained from the participants who agreed to take part in the study.

**Peer-review:** Externally peer-reviewed.

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