GSC Biological and Pharmaceutical Sciences

eISSN: 2581-3250 CODEN (USA): GBPSC2

Cross Ref DOI: 10.30574/gscbps

Journal homepage: https://gsconlinepress.com/journals/gscbps/

(RESEARCH ARTICLE)

Effectiveness of the optimized open poultry house YAPI-20.25® on the performance of Novogen Brown laying hens subjected to high densification

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GSC Biological and Pharmaceutical Sciences, 2025, 33(03), 051-060

Publication history: Received 27 October 2025; revised on 04 December 2025; accepted on 06 December 2025

Article DOI: https://doi.org/10.30574/gscbps.2025.33.3.0489

Abstract

Faced with increasing land pressure, optimizing livestock buildings appears as a strategy to increase stocking density without compromising performance or welfare. This study evaluated the impact of the optimized open poultry house YAPI-20.25® on the zootechnical performance of Novogen Brown laying hens reared at a density of 7.73 hens/m^2. A total of 1,700 pullets were monitored from 21 to 36 weeks of age and compared to standard genetic references. Measured parameters included feed intake, laying rate, egg weight, feed conversion ratio (FCR), and viability. Daily feed intake remained below the standard, without negatively affecting productivity. At 24 weeks, the laying rate reached 92.90%, very close to the reference, despite a slight delay in the onset of lay. From week 26 onward, the average egg weight exceeded the standard by more than 0.5 g. The feed conversion ratio remained efficient, reaching 1.67 compared to 1.83 for the standard at 36 weeks. Viability was slightly lower but not significantly different. Overall, the optimized open poultry house YAPI-20.25® allowed controlled densification without compromising performance or welfare, confirming its relevance as a solution adapted to land-use constraints.

Keywords: Densification; Zootechnical performance; Novogen Brown; Optimized open poultry house YAPI-20.25®

1. Introduction

Poultry farming is a strategic sector for food security, job creation, and poverty reduction in most countries around the world (Pica-Ciamarra and Otte, [1] ; Hoffmann *et al.*, [2] ; Kiprop *et al.*, [3]). The egg sector, in particular, is experiencing steady growth, driven by increasing demand for poultry-based animal protein, which is more affordable than red meat or fish (Singh *et al.*, 2022 [4] ; Akinola and Essien, [5]). However, this rapid expansion comes with numerous structural challenges, one of the most pressing being the optimization of farming space, at a time when land is becoming increasingly scarce and expensive, particularly in peri-urban areas (Naazie *et al.*, [6]). To address this issue, one solution is the densification of poultry buildings as a strategic alternative that increases production without requiring additional land (Schmidt, [7]). However, the high cost of closed housing systems that support densification poses a new challenge for less developed countries (Setiadi *et al.*, [8]). Stocking density, defined as the number of birds per square meter of usable floor area, directly affects zootechnical performance notably, such as feed intake, body weight, feed conversion ratio, laying rate, and egg weight, as well as animal welfare parameters (Feddes *et al.*, [9] ; Alig *et al.*, [10] ; Geng *et al.*, [11]). Several studies have shown that excessively high densities can negatively affect production in laying hens (Kang *et al.*, [12]). Indeed, in their study, authors observed that increasing the stocking density to 10 birds/m^2 led to a significant decrease in laying rate, egg weight, and feed intake in Hy-Line Brown laying hens. Moreover, other studies, such as Weimer *et al.*, [13] have shown that physiological parameters such as elevated corticosterone levels or an

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increased heterophil/lymphocyte ratio, indicate heightened stress in animals kept in confined spaces. However, most of these studies focused on increasing density without modifying the structure of the housing. Thus, less studied, the design of poultry houses in small-scale farms is important and deserves particular attention in future research. The present study evaluated the impact of the optimized open poultry house YAPI-20.25®, designed for increased stocking density in commercial laying hens, on production performance

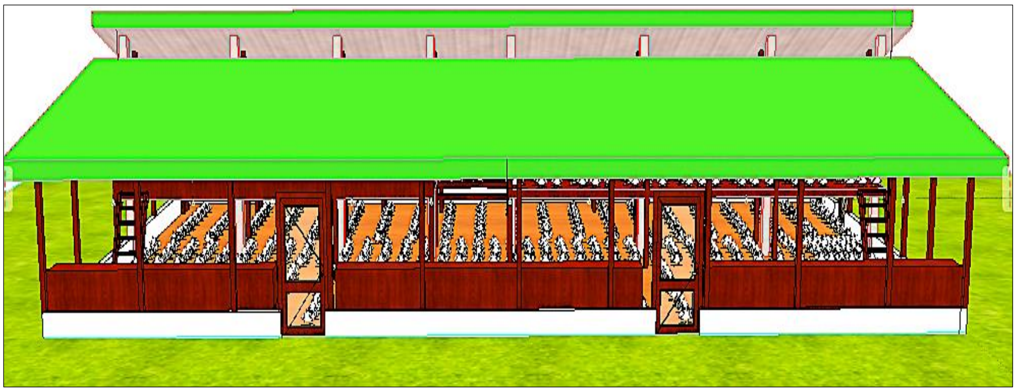
2. Material and methods

2.1. Experimental Site

This study was conducted in Dabou, located at 5°19′00″ N, 4°23′00″ W, in the Grands-Ponts region, about fifty kilometers from Abidjan city. The annual temperature generally ranges from 23 °C to 32 °C and rarely falls below 21 °C or exceeds 33 °C. The experimental site is situated along the Dabou–Pkass village axis, 300 meters from the coastal highway connecting Dabou to Grand-Lahou.

2.2. Optimized open poultry house YAPI-20.25®

The optimized open poultry house YAPI-20.25® (Figure 1) consists of a rearing building incorporating a central elevated platform in the middle of the structure and at the level of the ventilated roof, allowing for both floor-level and elevated rearing. It includes a low wall with posts every 2.5 m, made of solid wood pillars, reaching a height of 4 m from the concrete floor. The central pillars are aligned with the lateral pillars, and all pillars are fixed with concrete to withstand weather conditions and the weight of the roof structure. The building has a sloped, double-pitched roof made of colored metal sheets to reduce internal temperature, particularly around the central platform. For this trial, the Optimized open poultry house YAPI-20.25® measures 20 m in length, 11 m in width, with a lateral height of 4 m and a central height of 5 m. The central platform, elevated 2 m above the floor, is accessed via 2 m high steps. It measures 2 m wide and 19 m long, divided into two sections by a 1 m wide walkway. The peripheral wall is 0.30 m high, and the ventilated roof opening (lantern) is 0.5 m at the roof peak. Nesting boxes are arranged in rows, 1.30 m above the floor, 0.90 m from the wall, and 0.40 m from the low wall. Nests are positioned along the lateral surfaces in the building's longitudinal direction, with two rows of nests on each side of the main building and one row on each side of the central platform. Each nesting box measures 0.30 × 0.30 × 0.30 m (0.027 m^3). Perches are adjacent to the nests and have two levels: Level 1 at 0.50 m and Level 2 at 0.80 m above the floor. The watering system consists of suspended automatic bell drinkers. Lighting is provided by a photovoltaic system. The equipment ratio used in the Optimized open poultry house YAPI-20.25® was one feeder per 15 hens, one drinker per 30 hens, and one nest per five hens.



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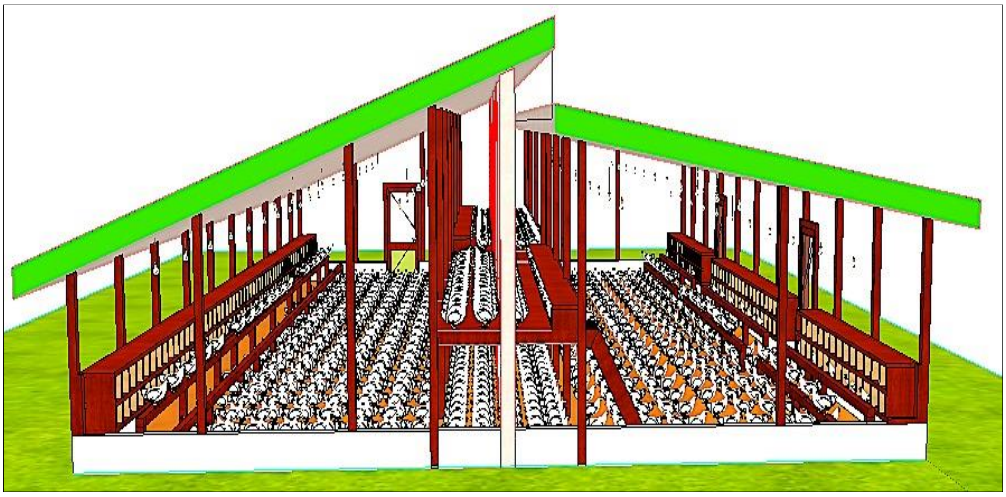


B

A: Optimized open poultry house YAPI-20.25® seen lengthwise; B: Optimized open poultry house YAPI-20.25® seen on width

Figure 1 Optimized open poultry house YAPI-20.25®

2.3. Experimental Animals

To evaluate the efficiency of the optimized open poultry house system YAPI-20.25®, 1,700 commercial Novogen Brown pullets, aged 21 weeks, were used and monitored until 36 weeks of age. The average body weight of the pullets at the start of the experiment was 1,600 ± 65.43 g. The pullets were sourced from the Poussin d'Or® hatchery of the company KOUDIJS® (Poussin d'Or, [14]). However, they had been received as one-day-old chicks, even though the experiment started when they were 21 weeks old.

2.4. Water and food consumption

In this study, water was provided ad libitum via automatic bell drinkers. Manual trough feeders, with one feeder per 15 pullets, were used, and layer feed 1 from KOUDIJS® was provided according to the quantities specified in the technical datasheet for the genetic standard, supplied by KOUDIJS® through its Poussin d'Or® subsidiary (Poussin d'Or, [14]). Table 1 shows the chemical composition of the feed used.

Table 1 Bromatological composition of KOUDIJS® Ponte 1 feed

Composition	Indicative Value
Crude protein (%)	16.00
Crude fat (%)	5.30
Lysine (%)	0.70
Methionine (%)	0.40
Calcium (%)	3.60
Phosphorus (%)	0.40
Metabolizable energy (kcal)	2800

(Poussin d'Or, [14])

2.5. Distribution of pullets in the open poultry house YAPI-20.25®

In the Optimized open poultry house YAPI-20.25®, the pullets were distributed based on 6 birds/m^2 on the floor, corresponding to 1,320 pullets for 220 m^2, and 10 pullets/m^2 for 38 m^2 on the central platform. This densification took into account the building height (4 m at the sides and 5 m at the center), which promotes good ventilation and rapid removal of ammonia from the litter for the floor-level birds. For the birds on the central platform, their proximity to the ventilated roof allows them to receive fresh air directly from the roof opening, providing effective ventilation. This experimental arrangement resulted in an overall density of 7.73 pullets/m^2, compared to 5 pullets/m^2 if only the floor area of the YAPI-20.25® were considered, with the objective of approaching floor densities of 8–10 pullets/m^2 typically used in closed housing systems (Poussin d'Or, 2023).

2.6. Pullets management

The results of this study were compared with the genetic standard of the strain, especially since all commercial layer farms use the strain's genetic standard as a benchmark. The pullets were fed according to the quantities prescribed in the guide, with preference given to the cooler hours of the day to minimize potential heat effects. Additionally, the birds were managed according to the prophylaxis program provided by KOUDIJS®. During the trial, the lighting was maintained at 16 hours of light per day. The following zootechnical parameters were then recorded during the management period.

2.6.1. Daily Feed Intake

Daily feed intake (DFI) is an essential parameter in the management of a laying hen flock. It allows for the assessment of the birds' actual nutritional requirements, monitoring of their health status, and optimization of production performance. It was determined using the following formula : DFI (g) = Quantity of feed offered (g) – quantity of feed remaining (g) / Total number of hens

2.6.2. Daily Laying Rate

The laying rate is an essential indicator for evaluating the performance, health, and profitability of a laying hen flock. It enables farmers to make informed decisions to optimize production and ensure the success of their operation. It is determined using the following formula :

Laying rate (%) = (Number of eggs laid per day / Total number of hens present) × 100

2.6.3. Average Egg Weight

The average egg weight (AEW) is crucial for evaluating production and quality, as it affects the total mass of eggs produced. The body weight of hens, particularly at 18 weeks, is linked to egg weight, and inadequate body weight can impact production. Additionally, the proportion of egg components (white, yolk, shell) is related to total egg weight, influencing overall quality. Monitoring the average egg weight is therefore important for production management and assessing the health of the hens. The following formula was used to determine the average egg weight :

AEW (g) = Sum of the weights of the eggs weighed / Total number of eggs weighed

2.6.4. Feed Conversion Ratio (FCR)

The feed conversion ratio (FCR) in laying hen farming measures the efficiency with which hens convert feed into production (eggs). A low FCR indicates better feed efficiency, as less feed is required to produce the same quantity of eggs, which is advantageous for the farmer. It was determined using the following ratio :

FCR = Quantity of feed consumed during a period / Weight gain during that period

2.6.5. Viability

The viability rate in poultry farming is a key indicator of flock health and performance. It allows for the assessment of the impact of diseases, environmental conditions, and management practices on bird survival. It was determined using the following formula :

Viability (%) = (Number of birds alive at the end of the trial / Number of birds at the start of the trial) × 100

2.7. Statistical Analysis

The data from this study were subjected to statistical analyses. Specifically, the means of feed intake, egg weight, and feed conversion ratio were compared to standard values using a one-sample t-test. As for laying and viability proportions, they were compared to standard proportions using a one-proportion z-test. Differences were considered statistically significant at $p < 0.05$. The software used was XLSTAT 2022.4.5.

3. Results

3.1. Daily Feed Intake of Pullets

Figure 2 shows the evolution of the daily feed intake of the pullets in the experimental group reared in the optimized open poultry house YAPI-20.25® compared to the standard feed consumption. Throughout the trial, the feed intake of the experimental pullets was lower than the standard, with no statistically significant difference ($p > 0.05$). The consumption curve shows four (4) phases. The first phase, from week 21 to week 25, is characterized by the pullets' feed intake gradually approaching the standard. Indeed, the difference decreased from 18.15 g in week 21 to 3.9 g in week 25. The second phase (weeks 26 - 27) shows a decline in consumption, with a difference of about 12 g between the two groups at week 27. In the third phase (weeks 28 - 32), feed intake improved again, narrowing the gap to 2 g at week 32. Finally, from week 33 until the end of the trial (phase 4), the pullets in the optimized open poultry house YAPI-20.25®consumed about 10 g less compared to the standard and this difference remained until the end of the trial.

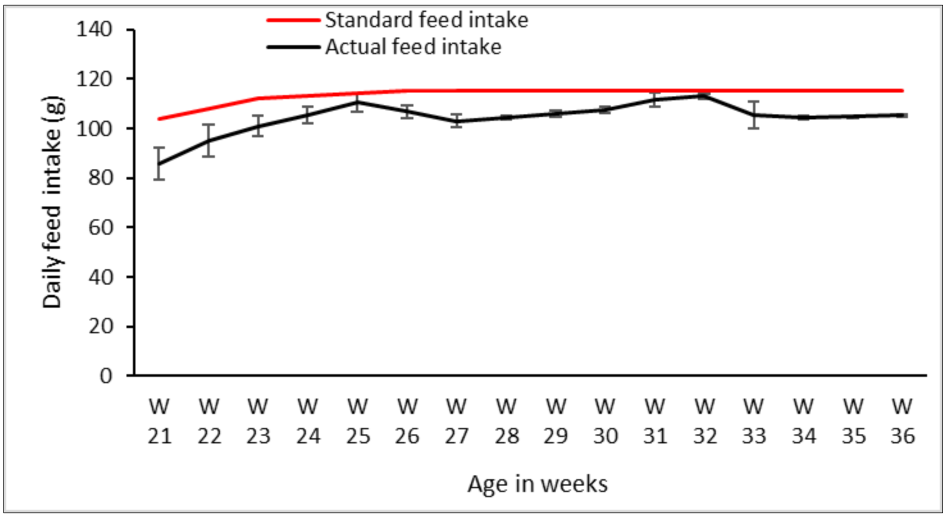


Figure 2 Daily feed consumption of Novogen Brown layers in the optimized open poultry house YAPI-20.25®compared to the standard

3.2. Impact of the optimized open poultry house YAPI-20.25® on laying rate

Figure 3 shows the laying curve, with a significant delay ($p < 0.05$) in the onset of laying observed in the experimental pullets compared to the genetic standard. Indeed, during the first week of the trial (week 21), the experimental group recorded a laying rate of 35.09%, representing a negative difference of 29.91% compared to the standard. Over the following three weeks, a rapid increase in laying allowed the experimental pullets to reach a laying rate of 92.90% versus 93.50% for the standard, with no statistically significant difference ($p > 0.05$). This rise continued until the peak laying period (weeks 25 to 30), with laying rates statistically similar to the standard ($p > 0.05$). During the stabilization phase (weeks 31 to 36), a non-significant drop in laying rate of 1.70% and 1.5% was observed in the experimental group during weeks 31 and 34 - 35, respectively ($p > 0.05$).

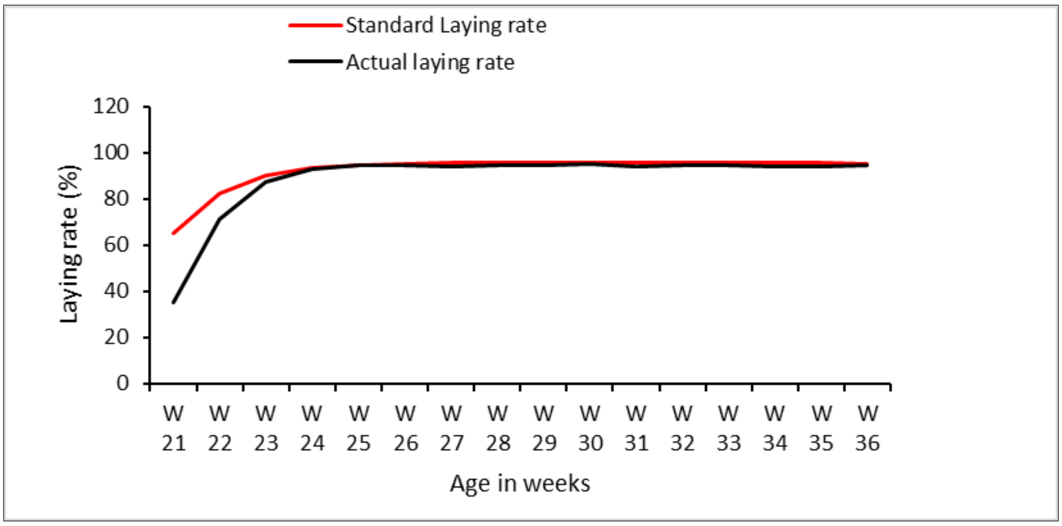
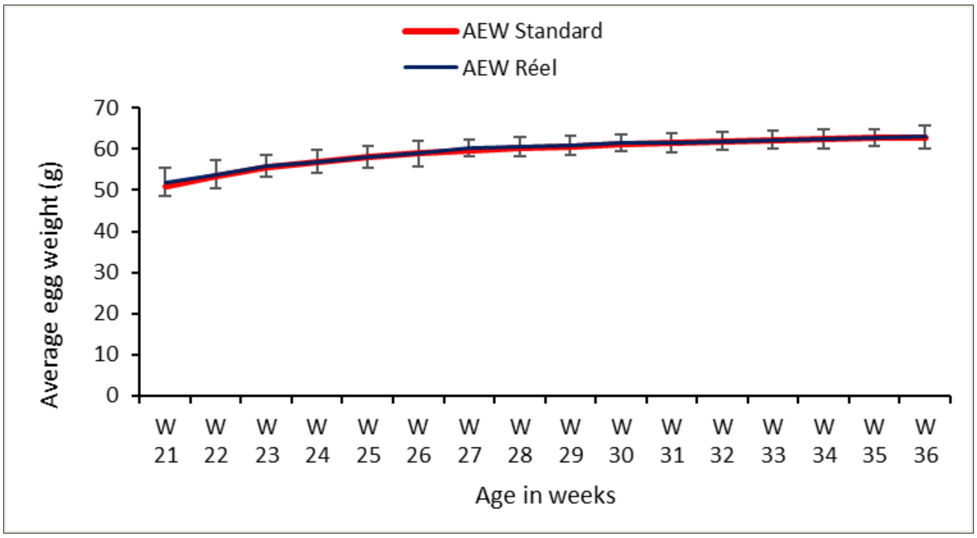


Figure 3 Effect of the optimized open poultry house YAPI-20.25®on the laying performance of Novogen Brown pullets compared to the standard

3.3. Effect of the optimized open poultry house YAPI-20.25® on egg weight

Egg weight increased steadily from week 21 to 36 in the experimental group, mirroring the standard group, with an almost linear growth (Figure 4). However, except for weeks 25 and 26, when the average egg weight of the experimental group was slightly lower than the standard, the experimental group recorded higher egg weights throughout the trial, although the differences were not statistically significant compared to the genetic standard. Moreover, from week 26 onwards, a slowdown in growth was observed, with a positive difference of approximately 0.5 g in favor of the experimental group.



AEW : Average Egg Weight

Figure 4 Effect of the optimized open poultry house YAPI-20.25®on the egg weight of Novogen Brown pullets compared to the standard

3.4. Weekly evolution of the feed conversion ratio (FCR)

Table 2 shows the weekly evolution of the FCR over a 16-week period (weeks 21 to 36), comparing the expected standard values with those actually observed in a flock of 1,700 laying hens. Overall, the observed FCR values are lower than the standard values. In week 21, the experimental flock recorded an FCR of 1.68 compared to 2.04 for the standard, representing a notable improvement, although the difference was not statistically significant ($p > 0.05$). This trend was consistent throughout the remaining weeks of the trial.

Table 2 Evolution of the feed conversion ratio of Novogen Brown pullets in the optimized open poultry house YAPI-20.25®compared to the standard

Age (weeks)	Feed Conversion Ratio (FCR)		*p-value*
	Standard group	**Real group**	
Week 21	2.04	1.68	*0.71*
Week 22	2.02	1.77	*0.06*
Week 23	2.01	1.81	*0.45*
Week 24	1.99	1.85	*0.08*
Week 25	1.96	1.90	*0.12*
Week 26	1.95	1.81	*0.11*
Week 27	1.93	1.73	*0.06*
Week 28	1.91	1.73	*0.06*
Week 29	1.89	1.75	*0.07*
Week 30	1.88	1.76	*0.06*
Week 31	1.87	1.82	*0.07*
Week 32	1.86	1.83	*0.78*
Week 33	1.85	1.70	*0.10*
Week 34	1.84	1.67	*0.10*
Week 35	1.83	1.67	*0.08*
Week 36	1.83	1.67	*0.08*

3.5. Hen Viability

Figure 5 presents the viability of Novogen Brown pullets reared in the optimized open poultry house YAPI-20.25® compared to the standard. Although the experimental flock howed a viability slightly below the standard, the difference remains 2% and not statistically significant ($p > 0.05$).

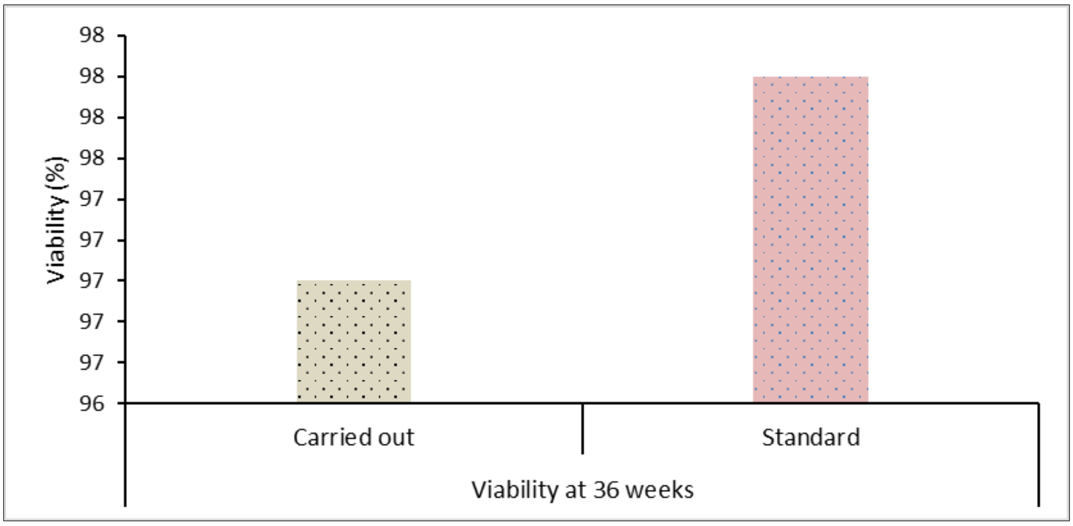


Figure 5 Viability of the 1700 Novogen Brown pullets compared to the standard

4. Discussion

The results obtained in this study show that the optimized building YAPI-20.25® makes it possible to significantly reduce feed consumption in laying hens while maintaining laying performance close to the genetic standard. This observation suggests an improvement in feed efficiency, probably linked to a reduction in metabolic expenditure and unnecessary energy losses (Xu e*t al*., [15]). The decrease in the feed conversion ratio observed in this building indicates that the energy resources from the feed are better directed toward egg production rather than maintaining homeostasis under environmental stress conditions. This supports the findings of Gao *et al*., [16], who demonstrated the direct influence of environmental parameters such as temperature, humidity, light, and ventilation on metabolism and nutrient absorption in laying hens. Similarly, Alig *et al*., [17] showed that housing systems with better environmental control promote increased feed efficiency, notably through an improved feed conversion ratio. Although laying began slightly later in the YAPI-20.25® building, this delay can be attributed to a transient adaptation stress to the new environmental conditions, particularly to changes in the lighting program and the timing of lay stimulation. This phenomenon was also reported by Wan *et al*., [18], who highlighted the impact of certain housing systems on sexual maturation and the initial performance of hens. The link between body development, delayed sexual maturity, and late onset of laying appears to be confirmed in this context. In terms of weight performance, the egg weight recorded in the optimized building exceeded the reference values of the genetic standard, although the difference was not statistically significant. This trend may be linked to a more favorable environment that allows for better expression of the hens' genetic potential, particularly regarding ventilation quality and the rapid removal of ammonia from the litter. Previous studies have demonstrated the detrimental effects of ammonia on performance and egg quality (Li *et al*., [19]; Rodríguez-Mengod *et al*., [20]), which supports the hypothesis that the improved microclimate of the YAPI-20.25® building could promote better productivity. The results obtained are also consistent with the findings of Ketta *et al*., [21], who showed that interactions between genotype, housing system, and calcium intake significantly influence egg weight, feed intake, and laying performance. These authors also observed a lower feed conversion ratio under improved housing conditions, which is consistent with the results of the present study. Regarding viability, although a slight decrease was observed compared to the standard, this difference was not significant. It could be related to occasional unfavorable microclimatic conditions, particularly during the first weeks of laying, a period during which cases of prolapse were recorded. However, the overall stability in mortality suggests that the optimized building effectively meets the animals' physiological needs. These results are consistent with those of Wan *et al*., [18] and Bonnefous *et al*., [22], who emphasized that more comfortable and better-regulated housing reduces stress and mortality, and improves overall welfare. Moreover, Li *et al*., [19] established a close correlation between environmental conditions and the viability of animals in production. Finally, the observations from this study reinforce the findings of several authors who state that housing optimization allows for better expression of genetic potential, particularly in terms of feed efficiency (Zhou *et al*., [23]). Improving thermal comfort, air quality, and light regulation constitutes important leverage for sustainable and efficient production.

5. Conclusion

The optimized YAPI-20.25® building enabled controlled densification without compromising the performance or welfare of laying hens. It did not negatively affect feed efficiency, egg weight, or laying rate, and it also ensured satisfactory viability. Thanks to the building's configuration, which provides good ventilation for effective thermal management, this model offers a sustainable solution adapted to land-use constraints. Following this study, a long-term evaluation of Novogen Brown hens' performance in the YAPI-20.25® building over a full production cycle would be feasible. Subsequently, a comparative analysis of animal welfare between the optimized open building and a high-density closed building could assess stress markers such as plumage condition and behavior. Finally, a study on the impact of the YAPI-20.25® building configuration on the microbiological quality of eggs and litter would allow comparison of bacterial loads of *Escherichia coli* and *Salmonella* spp. on eggshells and litter between the central platform and the floor space of the optimized building.

Compliance with ethical standards

Acknowledgments

We extend our sincere thanks to the NGO Développement et Valorisation de la Production Animale en Côte d'Ivoire (DeVPA-CI), registered under Association No. 0722/MATED/DGAT/DAG/SDVA with the Ministry of Territorial Administration and Decentralization of the Republic of Côte d'Ivoire. This research benefited from the support of the NGO DeVPA-CI for the establishment of the optimized open building YAPI-20.25®.

Disclosure of conflict of interest

The authors declare that they have no conflicts of interest related to this study."

Statement of ethical approval

Approval from an ethics committee regarding the use of animals was not required for this study, as it was conducted on a species whose conventional rearing and stocking density in this study are already typical for closed housing systems.

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