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Technical Note

Thermal Conditions of Laying Quail Sheds in Brazil

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Abstract: This study was conducted to survey the level of technification of quail sheds in Brazil. Data from 25 quail farms (5 in each Brazilian region) were collected by image analysis of videos available on the Internet. The analyzed variables were farm location, degree of technological adoption in quail sheds, housing conditions, structural conditions, wall conditions, and thermal comfort equipment. The data were subjected to descriptive analysis, and differences were assessed using the chi-squared test ($p < 0.10$). It was found that curtain walls were the most used system for air entry and renewal in quail sheds. Fan systems were present in only 12% of sheds, and evaporative cooling systems (or air conditioning) were observed in 4% of sheds, exclusively on large farms. Internal insulation was used in 20.83% of farms. In conclusion, Brazilian quail sheds have a low degree of technification; about 90% do not use implements such as ceiling, ventilation, and cooling systems. These conditions make it difficult to control environmental variables within quail sheds, impairing thermal comfort and, consequently, animal welfare and quail productivity.

Keywords: *Coturnix*; quail house; thermal comfort

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1. Introduction

Several regions of the planet are undergoing desertification, mainly in tropical countries [1,2]. Raising animals in sheds is emerging as an interesting strategy to meet animal requirements and gain better control over environmental conditions. Quail are considered environmentally resistant birds [3], as they are able to produce eggs even under conditions that would be challenging to other birds, such as laying hens. Because of this climate tolerance, quail farming is carried out in all regions of Brazil. The national flock size amounts to 15 million birds, which together produce 273,000 dozen eggs annually, according to data from the Brazilian Institute of Geography and Statistics [4].

Brazil has continental dimensions, with an area of 8,510,417,771 km^2 [4]. Because of its large territory, Brazil has a very wide climate variety, and each of its five regions has distinct characteristics. A study investigated winter and summer thermal extremes over a 10-year period. The results showed that the main regions used for animal production are in a situation of thermal emergency, with high temperatures in summer and abnormally low temperatures in winter [5]. Climate extremes are partially explained by the country's proximity to the Equator, which results in high solar incidence and high air temperatures. The climate is tropical or semi-arid in most of the country. Only part of the southern region is located below the Tropic of Capricorn and has a subtropical climate [6].

Achieving good control over environmental conditions on bird farms is paramount, as birds absorb heat from the environment and are particularly sensitive to high air temperatures and exposure to solar radiation [7,8]. For instance, laying sheds must be equipped with air circulation systems [9,10] in addition to air cooling systems [11], which are not typically used in quail breeding. It should be noted, however, that shed conditions must

be tailored to the specific characteristics of each region, ensuring the thermal comfort of the quails.

A previous study investigated the housing and management conditions of quail farms in Nigeria [12]. To the best of our knowledge, no such studies have been conducted in Brazil. In view of this gap, this study surveyed the level of technification of laying quail sheds in Brazil. The aims were to identify the main problems related to the rearing environment and demonstrate the importance of implementing techniques for the improvement of thermal comfort in quail farming facilities.

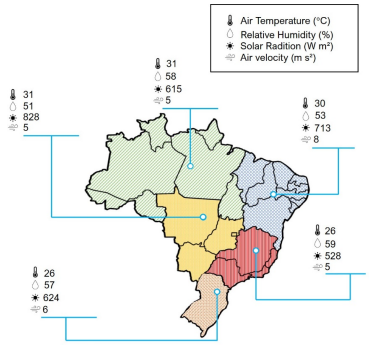
2. Materials and Methods

This study analyzed data from quail sheds located across all five regions of Brazil (Figure 1). Data were collected from free access information available on the Internet. The search terms used were "quail", "quail environment", "Japanese quail", and "quail breeding". From a total of 60 videos found on the World Wide Web, we selected those that showed thermal comfort facilities and equipment for Japanese laying quail.

Figure 1. Geographic distribution of quail sheds analyzed in Brazil.

Exclusion criteria for video analysis were videos published more than eight years ago, videos that did not show the interior of sheds, sheds housing fewer than 1000 birds, videos about quail farming as a hobby, ornamental quail farms, and farms that raised quail for slaughter. Subsequently, videos were assessed according to the following inclusion criteria: farms with egg production as a source of income and videos with sufficient image quality for analysis of shed conditions during egg laying. We also aimed to obtain a sample comprising quail farms distributed across the five regions of the country (North, Northeast, South, Southeast, and Central-West) and across three farm size categories. Farms were classified as small (1000 to 3000 birds), medium (3000 to 10,000 birds), or large (10,000 to 800,000 birds). The number of animals was mentioned in the videos. The final sample comprised 25 videos, including 5 farms from each geographic region. As for size, 8 farms were small, 8 were medium, and 9 were large.

The meteorological variables analyzed in this research were air temperature (°C), relative humidity (%), air velocity (m s^{-1}), and solar radiation (W m^{-2}). Meteorological data referring to each farm location in 2021 (Figure 2) were extracted from the National Institute of Meteorology database [13] of the Brazilian Ministry of Agriculture, Livestock, and Food Supply (MAPA). The quail shed variables analyzed in the study are described in Table 1.



(**a**)

Brazilian Region	Geographic Location		Climate Classification
	Latitude	Longitude	
North	−0°88′95″	−58°45′19″	Af, Aw, Am
Northeast	−8°78′86″	−42°64′76″	BSh, As, Af, Aw
Central-West	−14°42′17″	−52°75′27″	Aw, Cwa
Southeast	−18°87′58″	−46°41′03″	Aw, Cwa, Cwb
South	−24°72′57″	−49°29′68″	Cfa, Cfb

(**b**)

Figure 2. Five territorial regions of Brazil: (**a**) mean air temperature, relative humidity, solar radiation, and air velocity (adapted from INMET) and (**b**) geographic location (latitude and longitude) and climate classification (Koppen) of the 25 quail sheds included in the study.

Table 1. Quail shed variables analyzed in this study.

Category	Variables
Farm location	State City *
Degree of technology adoption	Farm size Quail management Egg management Excreta management
Housing conditions	Number of battery cages Cage arrangement Cage size
Shed structural conditions	Roof ridge vents Internal insulation Ceiling
Shed wall conditions	Curtains Other materials
Thermal comfort equipment	Sprinklers Cooling system Ventilation system

* The exact location of farms will not be provided for confidentiality reasons.

All selected videos allowed us to have a clear view of the interior of sheds, from the floor to the rooftop. Quantitative and qualitative parameters related to Japanese quail production were analyzed and compared between the categories of Table 1. Quantitative parameters were analyzed within farm size and geographic region categories, and qualitative parameters were analyzed within cage arrangement types (Table 2).

Table 2. Qualitative and quantitative parameters used for in-depth analysis of quail sheds.

Category	Parameter	Responses
	Qualitative variables	
Farm size [1]	Feed supply Egg collection	Automatic or manual
	Curtains Air circulation Evaporative cooling	Yes or no

Table 2. *Cont.*

Category	Parameter	Responses
Geographic region [2]	Ceiling	Yes or no
	Shed wall	Curtains, concrete, wood, open wall, or shade net
Thermal comfort equipment	Ventilation Cooling	Yes or no
	Quantitative variables	
Cage arrangement [3]	Number of birds per cage	8, 20, or 50
	Number of batteries	1, 3, 4, 5, or 6

[1] Farm size was categorized as large, medium, or small. [2] Regions were North, Northeast, Central-West, Southeast, or South. [3] Cage arrangement was categorized as pyramidal or vertical.

Two types of cage arrangement were observed, either vertical or pyramidal, both in battery mode (Figure 3).

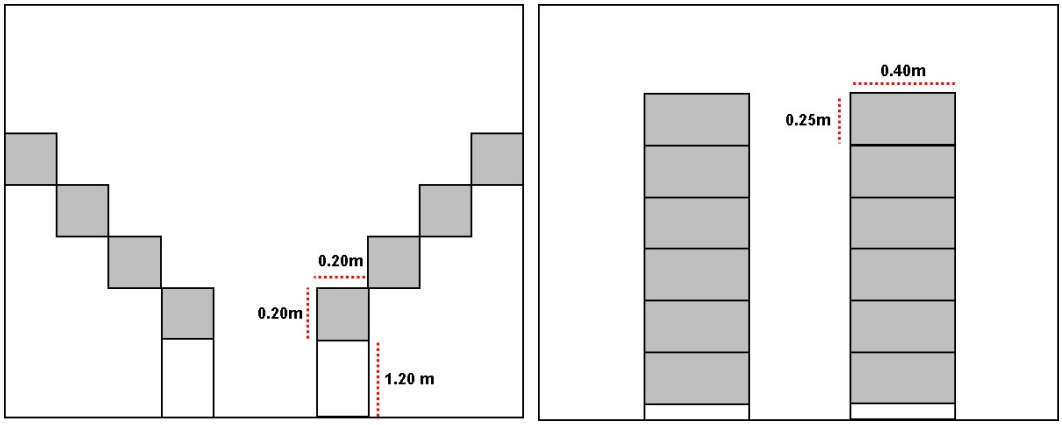


Figure 3. Cage arrangement of Japanese quail rearing systems: (**a**) small cages (0.20 × 0.40 × 0.20 m) with a pyramidal arrangement and (**b**) large cages (0.40 × 0.80 × 0.25 m) with a vertical arrangement.

The data were subjected to frequency analysis using the PROC FREQ procedure of SAS version 9.2. Probability analysis was performed by a chi-squared test at $p < 0.10$. The frequency analysis model is given by Equation (1):

$$f_{ri} = \frac{f_i}{n} \quad (1)$$

where f_{ri} is the relative frequency of categories (see Table 2), f_i is the absolute frequency of each category, and n is the total number of farms ($n = 25$). The relative frequency (f_{ri}, %) was calculated for each category and multiplied by 100.

3. Results

The degree of technology adoption in quail sheds varied significantly in terms of feed supply ($p < 0.10$). It was found that 55% of large and 20% of medium farms invested in automated feeders (Figure 3). Only large farms (with more than 10,000 housed quail) had highly advanced systems, and only 40% of farms had fully automated systems for feed supply, egg collection, and excreta collection (Figure 4).

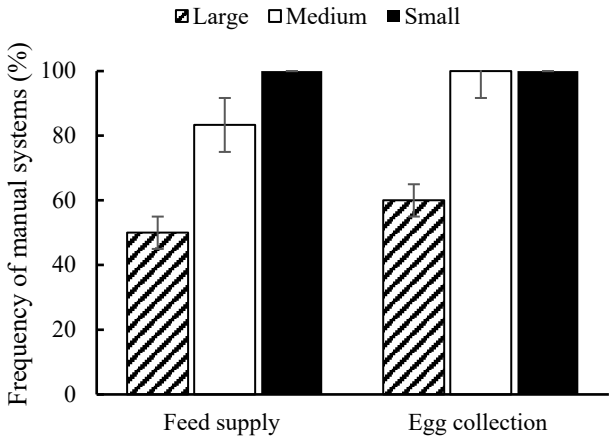


Figure 4. Percentage of farms with manual feed supply and egg collection systems according to farm size (n = 25).

Housing conditions varied according to cage size. Cages had a maximum capacity of 8, 20, or 50 birds (Figure 5A). The number of rows per battery varied from 1 to 6 (Figure 5B). There was a significant difference in cage size only for the pyramidal arrangement ($p < 0.001$). For vertically arranged cages, the number of rows per battery was either five or six (Figure 5B), not differing significantly ($p > 0.10$).

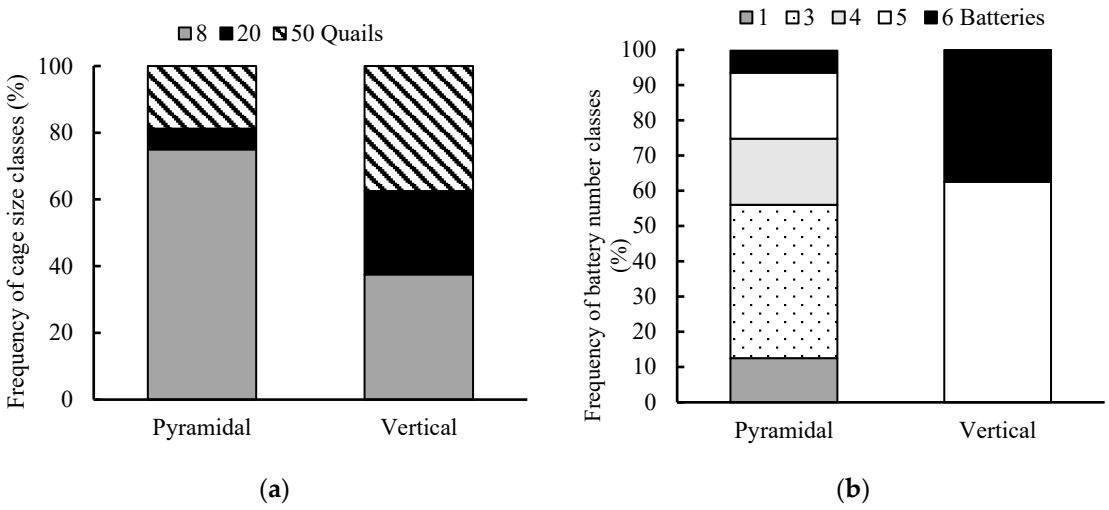


Figure 5. Frequency of (**a**) cage size and (**b**) battery number classes according to cage arrangement in quail farms (pyramidal, n = 17/25; vertical, n = 8/25).

The availability of thermal comfort equipment (curtains, fans, and evaporative cooling systems) varied according to farm size. Curtains were the most used device, being present in 70% of large, 60% of medium, and 37% of small-scale farms. Fans were present in only 12% ($p < 0.0001$) of farms, and evaporative or air conditioning systems were observed in only 4% of sheds, being exclusively used by large farms (Figure 6).

Farms differed significantly in shed roof material, ranging from fiber cement to metal and clay/ceramic ($p < 0.0001$). Because of their low cost, fiber cement roofs were the most frequently used, observed in 75% of farms. Here, only 12% of sheds had clay/ceramic roofs. Roof ridge vents were observed only in large farms, in 8.33% of these farms.

In conventional systems, most sheds were equipped with wall materials for the control of solar radiation and airflow. The main structures were shade nets and curtains (54.17%), fully open walls (16.67%), concrete walls with windows (12.50%), wood walls (8.33%), and walls with canvas and shade (8.33%), differing significantly between farms (p = 0.0012).

Shed wall materials differed according to region. Interestingly, among regions with higher solar radiation, only farms in the North used shade nets (33%). Fully open walls were used in 16.67% of farms in the Northeast and Southeast and 66% in the North (Figure 7).

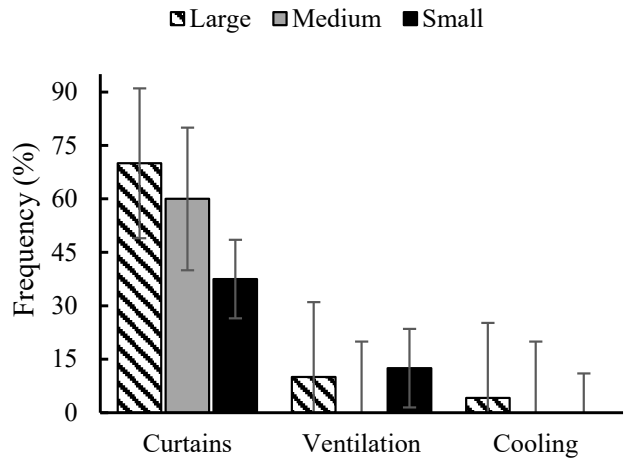


Figure 6. Percentage of quail sheds with cooling systems according to farm size (n = 25).

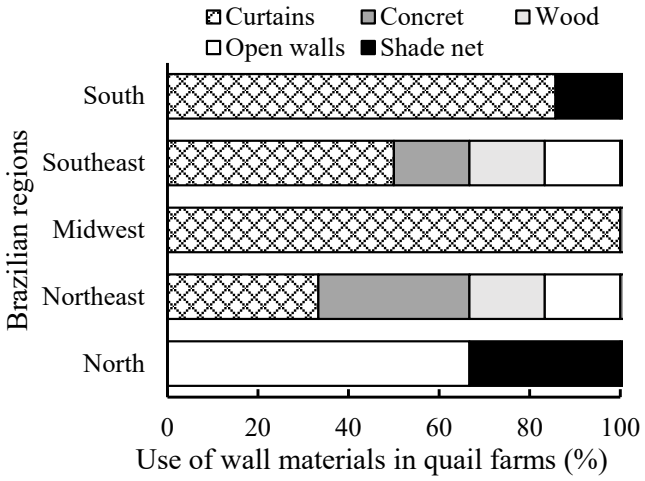


Figure 7. Wall materials used in quail sheds according to region (n = 25).

In the North (33.33%) and South (14.29%), sheds lacking curtains had shade nets made of black polypropylene cloth ($p < 0.05$) (Figure 7). Curtain color also differed between farms ($p = 0.03$); the majority (57%) had blue curtains, followed by yellow (29%) and gray (14%) curtains.

Internal insulation was observed in only 20.83% of farms, not differing according to farm size. Significant differences were observed between regions ($p < 0.10$): in the Southeast, 43% of farms had ceilings; in the North, 33%; and in the Southeast, 16.67%. In the Northeast and Central-West, no farm had sheds with insulation (Figure 8).

The use of ventilation and cooling systems differed according to farm size and region. Ventilation systems were observed in 8.33% of farms ($p < 0.0001$), and evaporative cooling in only 4% (Figure 9). Fans were observed in only two regions of the country: 16.67% of farms in the Northeast and the same percentage in the Southeast had fans ($p < 0.0001$).

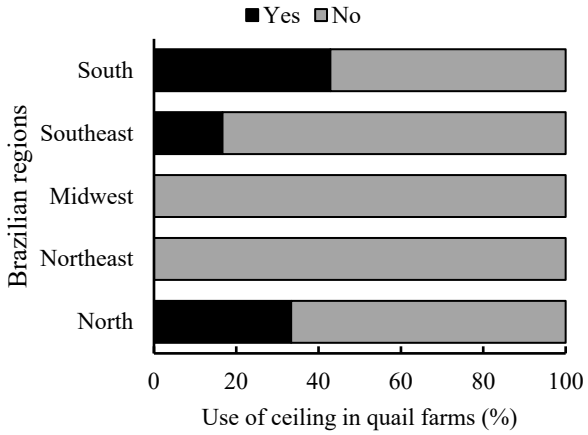


Figure 8. Frequency quail sheds with ceiling according to region (n = 25).

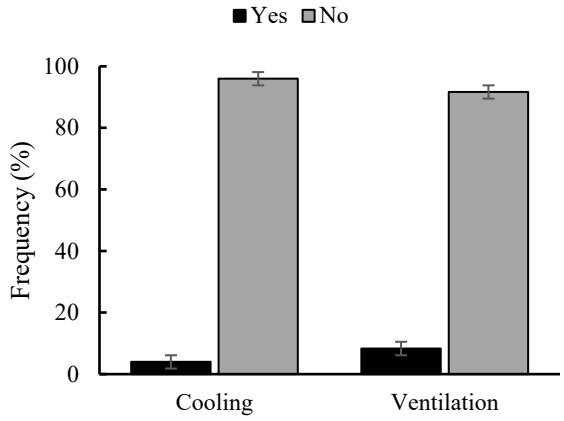


Figure 9. Frequency of ventilation and cooling systems in quail sheds (n = 25).

4. Discussion

The main goal of quail breeding is egg production. Japanese quail bred specifically for egg laying are widely used for this purpose [12]. Here, it was observed that nearly 90% of small-scale quail farmers also produce chicks, male meat, and breasts and thighs of discarded quail. In Brazil, small-scale and some medium-scale farmers carry out quail breeding as a family activity; therefore, the management of quail, eggs, and excreta is performed daily and fully manually. Technification of quail farms should improve feed supply, decrease egg losses (dirty, cracked, or broken eggs), and, consequently, enhance productivity.

Cage arrangement influences excreta collection. In the pyramidal system, no trays are used, and thus, excreta fall to the floor [3]. In sheds with cages arranged vertically, waste management should be performed more judiciously, as excreta are held in trays below cages, promoting accumulation. Excreta remain closer to birds, representing a possible sanitary problem and requiring more work to keep sheds clean. Farms with vertically arranged cages generally opt for automated systems of waste collection. Interestingly, 50% of large quail farms and 17% of medium-sized farms in Brazil used automated systems. An important advantage of automated systems, in addition to reduced handling, is that feed troughs can be filled several times a day, encouraging feed consumption [14].

In the study sample, birds were reared in battery cages arranged vertically or in a pyramidal system. Vertically arranged cages allow for better use of the shed area, increasing stocking density. However, such optimization of space results in close proximity of battery cages to the roof. Upper areas represent the warmest regions of the shed, as hot air is less dense and tends to rise and accumulate in this area [15]. The radiant thermal load absorbed by the roof is another contributing factor [16,17]. It was found that most farmers controlled

shed temperature using curtains and high roofs, regardless of farm size. High roofs provide more distance between birds and the roof and allow better air circulation inside the shed.

Rainfall variability, as highlighted by da Silva et al. [2], has direct effects on climate, vegetation, and water resources, making human activities more susceptible to climate impacts. In Brazil, the irregular temporal and spatial distribution of rainfall, added to the high air temperatures and radiation, accentuates tropical climate effects and increases the vulnerability of warmer regions to human activities, such as animal production. A country with a predominantly tropical climate, such as Brazil, may face serious problems with high solar radiation levels [17]. Meteorological variables (air temperature and solar radiation) had high averages throughout the year in all regions, namely in the South and Southeast (26 °C), Northeast (30 °C), and Central-West and North (31 °C). Solar radiation ranged from 520 to 828 W m^{-2} in the South and Central-West, respectively.

Reduction of radiation effects on the roof and installation of a ceiling could enhance thermal comfort. Use of roof insulation was greater in the South (42%), a region characterized by colder temperatures throughout the year. Insulation is applied to help maintain internal temperatures and prevent heat from escaping. Nevertheless, ceilings should be installed in hot climates as well [11], as they serve as a physical barrier to heat absorbed by the roof. Air has low thermal conductivity [18] and acts as an efficient thermal insulator between the ceiling and roof. This strategy represents an efficient and cheap manner to improve the thermal comfort of quail sheds.

Painting roofs white is an important technique to increase sunlight reflection, thereby minimizing radiation absorption via the roof [19]. Ideally, roof materials have high reflectivity and thermal emissivity [15]. Here, 13% of farms used metal roofs; a downside of this material is the noise produced while raining, which may cause discomfort and stress in quail, ultimately affecting egg production, aggravated by the high rainfall levels of the country. In regions with higher temperatures, it is suggested to use sandwich panels, which contain a layer of thermally insulating material, usually Styrofoam, between the outer and inner metal sheets.

Clay tile roofs are heavy, require a large support structure, and demand more maintenance. Nevertheless, this type of roof has an advantage over the others in terms of thermal control. Borges et al. [20] tested four types of roofs for quail sheds and found that ceramic roofing provided the best thermal comfort. A ridge vent is an opening in the roof that allows hot air to escape from the shed [15] and is indicated for warm regions. Ridge vents must be planned and implemented during shed construction; because of this, it was not observed in small and medium-sized farms (totaling 92%), which are generally adapted facilities.

As noted in a previous study, when the ambient temperature exceeds 29 °C, quail cannot effectively dissipate heat to the environment through sensible heat transfer. At 30 °C and above, heat loss changes to heat gain, causing heat stress in Japanese quails [21]. This thermal discomfort promotes the activation of heat loss through respiratory evaporation, which implies energy expenditure and, consequently, decreased egg production [22]. In the hotter regions of the current study, such as the North, Northeast, and Central-West, there was greater activation of respiratory evaporation, given the environmental characteristics and average air temperature of 30 °C. As in the Northeast, the Brazilian Central-West is characterized by a 6-month drought period, with temperatures exceeding 25 °C and relative humidity below 20%; these conditions promote an increase in respiratory frequency in quail [13].

Shed walls are necessary to facilitate air entry and renewal. Such renewal is necessary to obtain clean, cool air in warm regions and to allow the exit of possibly toxic gases, particularly in the case of sheds that remain closed in the winter. Walls also prevent direct exposure of quail to solar radiation, which could decrease bird welfare and worsen the thermal condition of the shed.

Sheds with fully open walls were more frequent in the North (33%), Northeast, and Central-West (16%), which are the regions closest to the Equator and, consequently, have

high solar radiation load. Solar radiation reached 828 W m^{-2} in the Central-West [17]. It is suggested to have non-fruit trees outside sheds to decrease solar radiation. In the case of sheds without blackout curtains, shade nets represent a great alternative for reducing radiant heat load. Shade nets are made of black polypropylene cloth and can block 70% to 90% of radiance, depending on the material.

Optimization of the construction processes by combining different techniques and materials can make buildings more sustainable and better adapted to the climate. By evaluating cost, time, and environmental comfort, this approach allows for better resource management, making buildings more effective for animal production. Application of these concepts in poultry housing for quail production is extremely important, as most sheds are open facilities, and increased animal welfare directly reflects on productivity [23].

Curtains ought to be closed at night to prevent a marked decrease in internal temperature. During the day, curtains should remain closed on the sides receiving sunlight to prevent direct exposure of animals to sunlight or the entry of radiation in cases where there is no natural (trees) or artificial (black polypropylene cloth) shading [24]. These factors are aggravated by the high temperature and air humidity of some regions, increasing the radiant heat load inside sheds and making environments thermally uncomfortable [25], promoting heat stress in quail.

Particularly in small farms, curtain management should be performed carefully. Farmers should close curtains on the side receiving solar radiation and keep the other curtains open to allow air exchange. In more modern sheds, it is suggested to place temperature sensors for automated opening and closing of curtains. With this technique, curtains can be adjusted according to the level of solar radiation inside the shed. Curtain color influences light intensity, comfort conditions, and bird behavior. A yellow color is indicated for low-latitude regions, where the weather is colder and days are shorter, helping save electricity [11,26,27].

The use of windows and curtains is widespread, but thermal comfort equipment, such as ventilation and evaporative cooling systems (evaporative plates), was used by only a few farms. Fans should be installed [9,28] to maintain air circulation and renewal. Another option is exhaust fans associated with evaporative plates in larger, fully enclosed, and air-conditioned systems in tunnel-type sheds. These systems may improve the thermal comfort of birds, although recommendations may vary according to region.

On hotter days, ventilation is useful for improving the thermal comfort of animals [9,28] and maintaining feed intake levels [29]. It is important to point out that ventilation only affects thermal sensation, defined by the average radiant temperature. Air temperatures are effectively decreased only when fans are associated with sprinklers and/or nebulizers. Therefore, because the North, Northeast, and Central-West have average air temperatures above 30 °C and high solar radiation (615 to 828 W m^{-2}), it is recommended to use both ventilation and cooling systems to improve the thermal comfort of quail.

Sprinklers are indicated for regions with dry and warm air (Central-West and inland Northeast). However, air humidity is high during most of the year in northern regions. Care must be taken not to increase the relative humidity of the shed excessively. Thus, the height and arrangement of the sprinkler system must be taken into account. It is necessary to alter the outlet pressure and perform maintenance and cleaning of sprinkler nozzles when necessary. These factors can help guarantee complete evaporation of water before reaching quail, which is not indicated.

Quail thermal comfort is essential for production. The suggested adjustments to quail sheds are important for maintaining the thermal balance of animals [8,30]. Birds in a thermally comfortable environment are able to maintain zootechnical indices [31], feed intake, feed conversion, egg production, and high laying rates (>85%) [32,33]. Furthermore, eggshell quality is enhanced, which is crucial for minimizing losses that may occur between egg production to egg processing [34].

Negative effects on egg production and bird health may be attributed to nutritional deficits or thermal discomfort promoted by excessive heat [35]. One sign of excessive heat

is panting for a long time with an open beak [36] in an attempt to dissipate heat and cool the body [22]. This is a point of concern, because a prolonged increase in respiratory rate causes nutrient imbalance, particularly calcium and phosphorus, allocated to regulate body homeostasis [37]. Consequently, these minerals are not carried to the uterus, where calcium deposition occurs for eggshell formation [37–39]. As a result, laid eggs may be soft, cracked, or thin-shelled.

The quail farms assessed in this study were found to have a low degree of technification, with a low use of thermal comfort equipment. Given that Brazil has continental dimensions and a tropical climate characterized by higher temperatures and solar radiation (annual means of 30 °C and 828 W m^{-2}, respectively), measures need to be taken to improve the bird's thermal comfort. Such efforts are particularly important in the current scenario of heatwaves, which are projected to worsen over the years because of global warming and increased desertification [1,2].

5. Conclusions

Quail sheds have a low degree of technification in Brazil. The majority (90%) do not use ceilings, ventilation, or cooling systems. This makes it difficult to control environmental variables, impairing thermal comfort, animal welfare, and quail productivity. Given that most sheds do not have air conditioning systems, the regions with the most suitable climatic conditions for quail farming are the Southeast, Northeast, and South, which currently have the highest quail egg production rates. However, some improvements may increase the efficiency of external and internal elements of quail sheds, thereby increasing animal welfare. Painting the roof with white paint and installing a ceiling on the inside may promote radiation reflection. To block radiation from entering the shed, curtains and shade nets are recommended. Air cooling or sprinkler systems are the most efficient means of reducing air temperature and facilitating heat dissipation, preventing an increase in quail energy expenditure. Fans can be used to promote air circulation and renewal when air temperatures are below 28 °C.

Author Contributions: E.M.d.O., J.V.d.N.M. and J.B.T.: Conceptualization and project administration; E.M.d.O., J.V.d.N.M. and L.d.F.R.: data curation; E.M.d.O., L.d.F.R. and S.T.N.: methodology and formal analysis; E.M.d.O., S.T.N. and T.C.d.S.: data analysis; E.M.d.O., S.T.N., J.V.d.N.M., L.d.F.R., J.B.T. and T.C.d.S.: writing—original draft; E.M.d.O., J.B.T. and T.C.d.S.: writing—review and editing. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The data were collected from reports with free access available on the Internet on YouTube, and meteorological data were extracted from the database of the National Institute of Meteorology (INMET), which is part of the Brazilian Ministry of Agriculture, Livestock, and Food Supply (MAPA).

Conflicts of Interest: The authors declare no conflict of interest.

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