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A Mobile Application to Follow Up the Management of Broiler Flocks

Angel Antonio Gonzalez Martinez [1], Irenilza de Alencar Nääs [1,*], Jair Minoro Abe [1] and Danilo Florentino Pereira [2]

[1] Graduate Program in Production Engineering, Universidade Paulista, R. Dr. Bacelar 1212, São Paulo 04026-002, Brazil; aagmartinez@gmail.com (A.A.G.M.); jair.abe@docente.unip.br (J.M.A.)
[2] Department of Management, Development and Technology, School of Science and Engineering, São Paulo State University—UNESP, Tupã, São Paulo 17602-496, Brazil; danilo.florentino@unesp.br
* Correspondence: irenilza.naas@docente.unip.br

Abstract: Broiler meat is one of the most consumed meats worldwide. The broiler production system poses several challenges for the producer, including maintaining environmental conditions for rearing. The popularization of mobile devices (smartphones) among people, including those with lower incomes, makes it possible for specialist systems to be developed and used for diverse purposes through Apps (mobile application). The present study proposed the development of a mobile application to help farmers follow up on-farm flock management. We retrieved rearing environment and flock data from commercial broiler farms that complied with broiler-producing standards and followed the breeders' recommendations. Data were organized and normalized to serve as the basis for the software. We specified a performance index based on the average environment and flock-based data. The language used for the application development was Python compatible with the GNU GPL (General Public License), which has a vast library of ready-made functions. For the graphical interface, we selected Kivy and KivyMD framework. The developed mobile application might help farmers evaluate broiler rearing conditions on-farm during the flock's growth and grade the flock using a performance index.

Keywords: flock performance; broiler production; performance index

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1. Introduction

Broiler chicken (*Gallus gallus domesticus*) production is a competitive meat chain with a short production cycle. It does not present religious limitations and has a low-cost production, attracting consumers from different social classes [1,2]. Providing an optimum indoor environment (air quality, temperature, humidity, air velocity, and gas concentration) with the lowest possible cost is essential to improve broiler production [3].

Air quality plays a vital role in broiler production. Ammonia (NH_3) is aggressive for broilers when trespassing certain limits [4–6]. Differences in production management techniques, ambient temperature, and flock density do not explain variations in the concentration of NH_3 in broiler flocks [7,8]. However, the current literature has pointed out how ambient humidity and litter management practices are critical factors in generating indoor emissions [8,9]. Air movement inside broilers' houses is essential for maintaining indoor air quality and increasing the birds' heat loss by convection, increasing beneficial heat exchange [10].

Indoor climate control requires considerable energy consumption and is fundamental in broiler houses [11,12]. It strongly influences the birds' health, growth, and performance and affects farm profits [13,14]. The rearing environmental temperature must be set within the thermal neutral zone to provide appropriate flock productivity [10]. Similarly, in the comfort temperature zone (CTZ), the energy fraction used by birds for maintaining their homeothermy is at a minimum; therefore, most of the energy supplied by feed is used for growth and meat production. Departure from the temperatures within the CTZ leads to an imbalance in the flocks' metabolisms, causing negative consequences [11,15]. However, most broiler house cooling system controllers are based on dry-bulb temperatures. Martinez et al. [16] developed a heuristic model relating the broiler rearing environment to dry-bulb temperature, relative humidity, air velocity, and ammonia concentration arrays. The model was centered on flock-based and environmental variables and predicted the suitability of the rearing conditions.

Cutting-edge technology, involving information technology (IT), remote sensing, robotics, cloud computing, Internet of Things (IoT), and Big Data assessment, can improve livestock production, expanding the benefits of rearing environmental control [17,18]. Mobile applications (Apps) have been developed lately to help farmers monitor and assess livestock growth and production in real-time as part of the Precision Livestock development [19–21]. These Apps include basic statistics tools that provide indicators immediately after flock assessment and potentially calculate changes from previously collected data. Apps allow the input of the main characteristics of housing conditions, flock characteristics, and age at assessment. Data might contain information related to independent variables and the corresponding assessment results when exported. Smartphones are handheld personal computers that have revolutionized communication technologies and information portability [22]. Currently, practically all people have mobile devices with reasonable processing capacity and access to the Internet, which they use for diverse purposes [23]. In this scenario, specialist Apps have great potential to improve decision-making in productive systems.

In the current literature, we did not find an App developed for following up on the suitability of flock rearing conditions based on data from broilers and the rearing environment. Therefore, the present study aimed to develop an App to help farmers evaluate the suitability of broiler rearing conditions during the flock's growth and grade the flock's performance.

2. Materials and Methods

The present study retrieved data from Brazilian commercial broiler farms that complied with broiler-producing standards and followed the breeders' recommendations.

In the database, we used historical data from four types of houses named for the lateral closure curtain colors and material (Blue House, Dark House, Solid Wall, and Giant). For each house, 52 measurements were taken twice on the same day (bird age), once in the morning and once in the afternoon. We recorded data in one flock in winter and another in summer and analyzed them. These measurements were taken for ages 21, 28, 35, and 42 days. Since the risk in performance during production in tropical countries is higher after the heating is removed after brooding, we focused our study after the 21st day of growth. A complete description of the experiment, methods, and details of husbandry and management was given in [16].

2.1. Variable Treatment for App Development

For each group of 52 measurements, we calculated the average of each of the measured quantities per season and per period (morning and afternoon) for the variables carbon dioxide (MCO_2) and ammonia (MNH_3), temperature (MT), air velocity (Mvair), and relative humidity (MU). Tables 1 and 2 summarize the data for 21 days old broilers.

Table 3 is adapted from [24], provides the comfort temperature for broilers (°C) as a function of age and relative humidity of the environment (%), and was used as the basis for calculating the normalized index of temperature and humidity.

Table 1. Example of variables' mean values for 21 days old broilers.

			Mean Values of Variables				
Age	**Season**	**Period**	**MT**	**MH**	**MVa**	**MCO_2**	**MNH_3**
21	W	M	24.18	65.31	0.18	546.15	11.6
21	W	A	27.88	41.51	0.34	15.14	4.52
21	S	M	25.25	59.22	0.39	35.34	3.49
21	S	A	27.01	47.23	0.79	15.14	2.29

W = winter; S = summer; M = morning; A = afternoon; MT = mean value of ambient temperature (°C); MH = mean value of relative humidity (%); MVa = mean value of air velocity (m/s); MCO_2 = mean concentration value of CO_2 (ppm); MNH_3 = mean concentration value of NH_3 (ppm); n = 52 measurements.

Table 2. Example of the Variables' Normalized Mean Values for the broilers 21 days old.

niTH	**$niNH_3$**	**niVar**	**$niCO_2$**	**PI**	**PI**
0.93	0.5	1.0	0.75	0.8	Good
0.96	1.0	0.75	1.0	0.93	Excellent
0.94	1.0	0.75	1.0	0.92	Excellent
0.93	1.0	−1.0	1.0	−1.0	Inadequate

niTH = normalized temperature and relative humidity index value; NH_3 = normalized ammonia index value; Var = normalized air velocity index value; CO_2 = normalized carbon dioxide index; PI = performance index. PI is the weighted arithmetic mean; in this example, the weights were equal to one, but they could change depending on the genetic strain.

Table 3. Limits adopted for temperature and relative humidity index values (TempHum).

	Temperature and Relative Humidity Index Value (TempHum)					
	MU $\geq$ 80%	**70% $\leq$ MU < 80%**	**60% $\leq$ MU < 70%**	**50% $\leq$ MU < 60%**	**40% $\leq$ MU < 50%**	**MU < 40%**
Age (d) (I)			**CTZ (°C)**			
I = 1	33	33	33	33	33	35
I = 2	32	32	32	32	32	34
I = 3	31	31	31	31	31	33
I = 4	30	30	30	30	30	33
I = 5	30	30	30	30	30	32
I = 6	29	29	29	29	31	31
I = 7	29	29	29	29	31	31
I = 8	28	29	29	29	31	31
8 $\leq$ I <12	27	28	28	29	31	31
12 $\leq$ I <16	26	27	27	29	31	31
16 $\leq$ I <20	25	26	26	28	30	30
20 $\leq$ I <24	24	25	26	27	29	30
24 $\leq$ I <30	23	24	25	27	29	29
30 $\leq$ I <35	22	23	25	26	28	28
I > 35	21	22	24	25	27	27

I = broiler's age; MU = mean relative humidity; CTZ = broiler comfort temperature as a function of the relative humidity. Adapted from [24].

For calculating the niTH index, we considered the range of the CTZ (broiler comfort temperature as a function of the relative humidity) and the mean ambient temperature (mt) as shown in Equation (1):

$$niTH = 1 - \frac{abs(CTZ - mt)}{CTZ} \quad (1)$$

where CTZ = broiler comfort temperature as a function of the relative humidity, mt = mean ambient temperature (°C), and abs = absolute value.

When relative humidity is <40% or >80%, then niTH = –1. Such a scenario already classifies the housing environment as inadequate. In Tables 4–8, we present the normalization of environmental control indices for each measured variable.

Table 4. Index normalization ranges for ammonia concentration ($niNH_3$) generated from field-recorded data.

Limits	$MNH_3 \geq 20$	$15 \leq MNH_3 < 20$	$10 \leq MNH_3 < 15$	$5 \leq MNH_3 < 10$	$MNH_3 < 5$
$niNH_3$	−1	0.25	0.5	0.75	1

MNH_3 = mean amount of ammonia in the environment (ppm).

Table 5. Index normalization ranges for air velocity (niVar) generated from field-recorded data.

Age (I) Range (Days)	$MVa \leq 0.5$	$0.5 < MVa \leq 0.75$	$0.75 < MVa \leq 1.5$	$1.5 < MVa \leq 2.0$	$1.5 < MVa \leq 2.0$
$I \leq 21$	1	0.75	−1	−1	−1
$21 \leq I \leq 28$	1	0.75	0.5	−1	−1
$28 \leq I \leq 35$	−1	1	1	−1	−1
$35 \leq I \leq 42$	0.5	1	0.75	0.5	−1

MVa = mean air velocity (m/s); I = broiler age.

Table 6. Index normalization ranges for carbon dioxide ($niCO_2$).

Ranges	$MCO_2 \leq 300$	$300 < MCO_2 \leq 600$	$600 < MCO_2 \leq 900$	$900 < MCO_2 \leq 1200$	$MCO_2 > 1200$
$niCO_2$	1	0.75	0.5	0.5	−1

MCO_2 = mean concentration of carbon dioxide in the environment (ppm).

Table 7. Normalized index description.

Normalized Index	Description
niTH	Normalized index of temperature vs. humidity
$niNH_3$	Normalized index of ammonia concentration
$niCO_2$	Normalized Index of carbon dioxide concentration
niVar	Normalized index of air velocity

Table 8. Weights for calibration of the results.

Variable	Value	Description
wTH	1	Weight for temperature humidity
wNH_3	1	Weight for ammonia
wCO_2	1	Weight for carbon dioxide
wVar	1	Weight for air velocity

2.1.1. Description of the Normalized Index for Ammonia Concentration ($niNH_3$)

The normalized index for ammonia concentration was found based on the intervals of the values recorded in each of the four houses (Table 4).

2.1.2. Description of the Normalized Index for Velocity Air (niVar)

Analogously, from the air velocity data for all the houses, intervals of air velocity as a function of the age of the birds were obtained, which are shown in Table 5.

2.1.3. Description of the Normalized Index for Carbon Dioxide ($niCO_2$)

The normalized index of CO_2 ($niCO_2$) ranges was calculated in the same way using normalized values of the CO_2 concentration from the four houses and are shown in Table 6.

2.1.4. Calculation of the Normalized Performance Index (PI)

With the normalized indices considering the growth period from 21 to 42 d-old broilers, weighting was carried out to obtain a situation index that would categorize the situation of the housing environment.

Tables 7 and 8 describe the meanings of the normalized indices used in calculating the PI described in Table 9.

Table 9. Limits adopted for using the performance index (PI).

Limits Adopted	PI Classification
PI $\geq$ 0.9	Excellent
0.6 $\leq$ PI < 0.9	Good
0.4 $\leq$ PI < 0.6	Moderate
PI < 0.4	Inadequate
PI = -1	Inadequate

PI = performance index.

Equation (2) is the sum of the weights associated with each normalized index and constitutes the denominator of Equation (3), which is a weighted average of the indices as a function of the weights. These weights allowed us to calibrate the performance index in such a way that it was more suited to, for example, the breed of birds.

$$\text{sumweight} = \text{wTH} + \text{wNH}_3 + \text{wCO}_2 + \text{wVar} \tag{2}$$

where sumweight is the sum of the normalized weights and wTH, wNH_3, wCO_2, and wVar are the weights associated with the normalized indices described in Table 8.

$$\text{PI} = \frac{(\text{niTH} * \text{wTH}) + (\text{niNH}_3 * \text{wNH}_3\text{a}) + (\text{niCO}_2 * \text{wCO}_2) + (\text{niVar} * \text{wVar})}{\text{sumweight}} \tag{3}$$

where niTH, niNH_3, niCO_2, and niVar are the normalized indices described in Table 7. Table 9 shows the values for the performance index (PI).

Figure 1 illustrates a flowchart of the steps of data input, management approach, and flock evaluation.

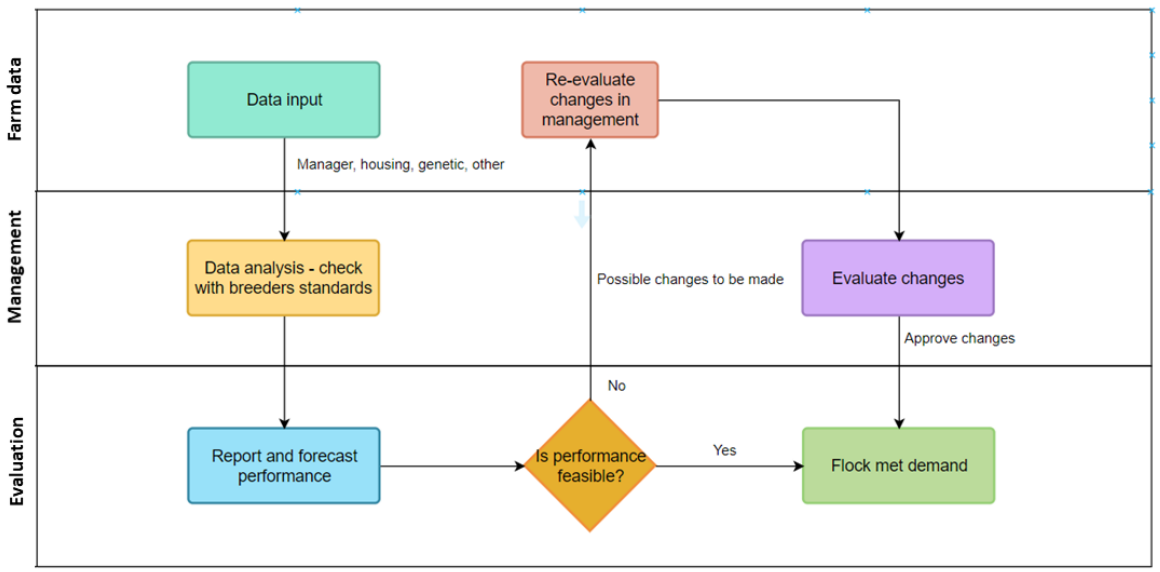


Figure 1. Flowchart of data input steps, management approach, and flock evaluation. Source: Developed by the authors.

The language in which the application was developed was Python. This language has a vast library of ready-made functions and extensive literature to support it [25–27]. It provided us with a great arsenal to perform data analysis in many possible ways. For the graphical interface, we selected a Kivy and KivyMD framework. Kivy is a free and open-source Python framework for developing mobile Apps and other multitouch application software with a natural user interface (NUI). It is distributed under the terms of the MIT License and can run on Android, iOS, Linux, macOS, and Windows. KivyMD is a collection of material design-compliant widgets for use with Kivy [28].

Input data (Table 10) can be supplied to the application manually or by an Excel spreadsheet. These data are stored in a database with SQLite and an on-file database.

Table 10. Application input data.

Input	Description
House	Type of house used during growth
Genetics	Broiler breed
Age	Age (d)
Season	Summer or Winter
Period	Morning or Afternoon
Temperature	Room temperature (°C)
Humidity	Humidity (%)
Velocity Air	Air speed (m/s)
CO_2	Carbon dioxide concentration (ppm)
Ammonia	Ammonia concentration (ppm)

2.2. Schematic of the App Functions

The application receives information from the environment in two ways. One way is manual input, wherein a user provides the data, and the other is by loading an imported Excel spreadsheet. After the data input, the data can be observed in reports shown on the App screen.

Figure 2 shows how the App operates using the housing environment and flock data, interactions with the user, a visualization of the App screen, and the possible outputs. The App was initially developed for Brazilian users; therefore, the input and output results are written in Portuguese.

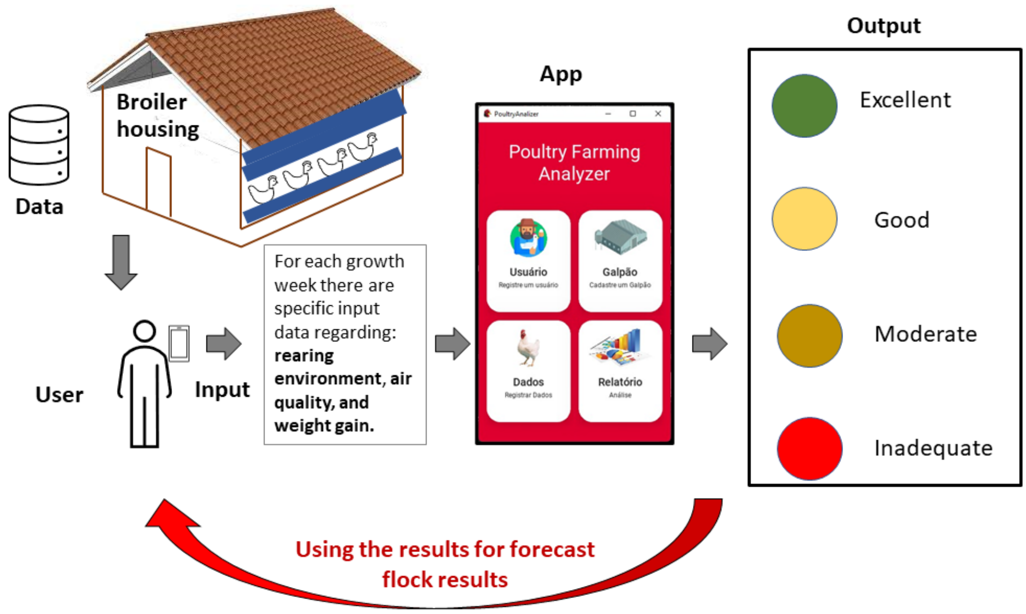


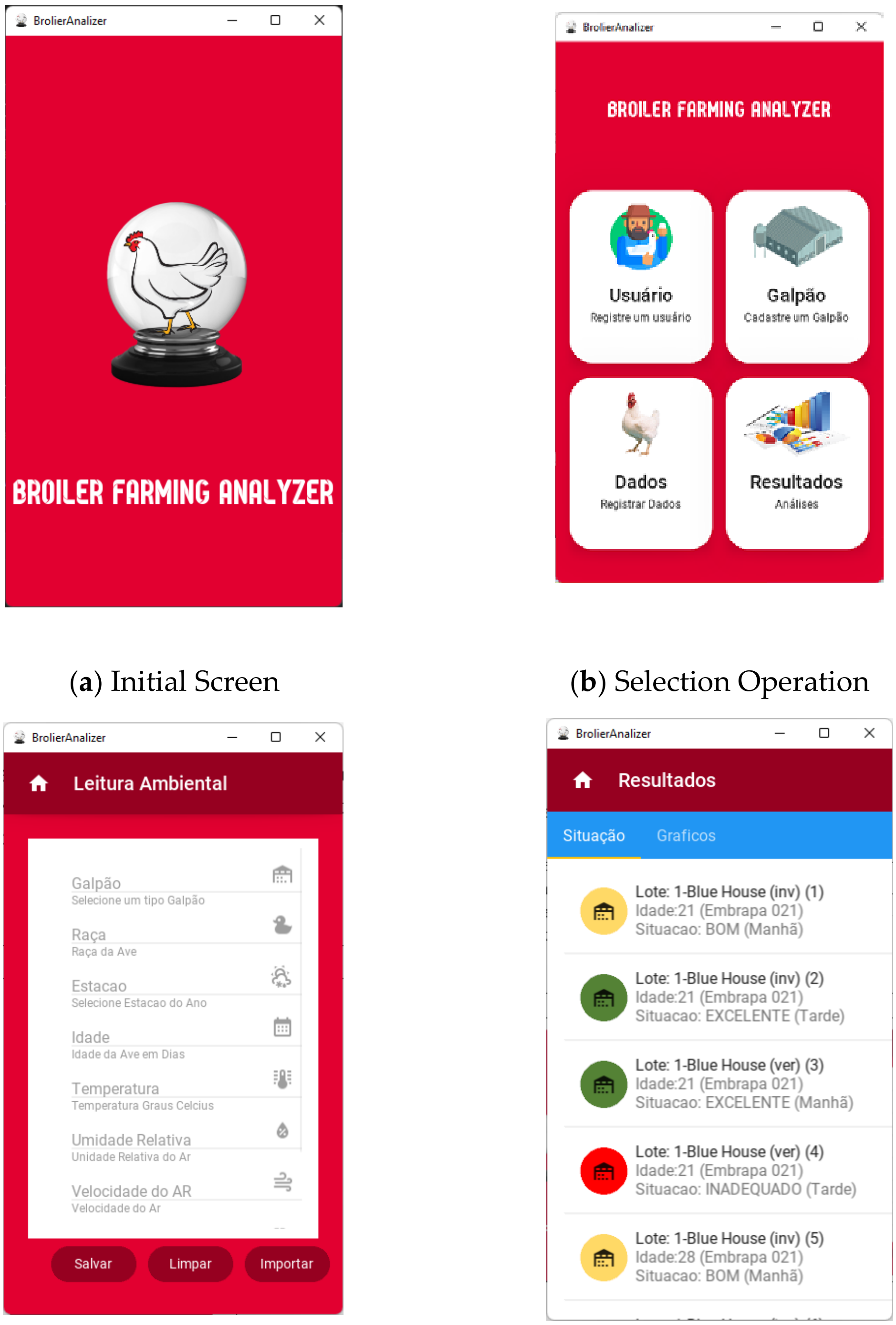
Figure 2. Schematic of App information: data input, flow, and output. Source: Developed by the authors.

3. Results

This section presents the developed App's characteristics and the results from simulations using field data to provide flock performance.

3.1. Sequence of the App Screens

Figure 3 presents projected screens to show the initial screen followed by the selection of the operations performed by the App. The next screen is related to the input data inserted manually or imported from a spreadsheet. The results screen presents the PI for the input data related to a specific flock.



(**a**) Initial Screen (**b**) Selection Operation

(**c**) Input Data (**d**) Results

Figure 3. The operational sequence of the App. Source: Developed by the authors.

3.2. Validation Results Using Recorded Field Data

In Table 11, we present results generated from field data for birds 35 d old. For instance, flocks in the Giant house during the summer in the morning with ambient temperature 24.9 °C, 81% relative humidity, CO_2 concentration 343.9 ppm, and NH_3 concentration 8.2 ppm were judged to have inadequate PI, for that particular conditions.

Table 11. Comparison of performance indices for the age of 35 days.

House	Age	Season	Period	MT	MH	MVa	MCO_2	MNH_3	PI
Blue House	35	W	M	23.6	65	0.80	138.5	5.8	Good
Blue House	35	W	A	26.3	52	1.15	30.3	4.4	Excellent
Blue House	35	S	M	26.8	58	1.14	21.6	3.1	Excellent
Blue House	35	S	A	29.0	52	1.15	6.45	2.5	Excellent
Dark House	35	W	M	23.6	70	0.87	242.3	5.6	Good
Dark House	35	W	A	24.8	66	1.46	36.8	2.6	Excellent
Dark House	35	S	M	25.1	82	0.97	97.4	6.4	Inadequate
Dark House	35	S	A	24.4	77	1.29	62.7	6.7	Good
Giant	35	W	M	23.5	71	0.47	1001.4	12.1	Good
Giant	35	W	A	26.2	57	0.93	243.0	6.1	Good
Giant	35	S	M	24.9	81	0.56	343.9	8.2	Inadequate
Giant	35	S	A	24.1	82	0.81	198.3	6.2	Inadequate
Solid Wall	35	W	M	22.9	67	1.06	60.6	5.2	Good
Solid Wall	35	W	A	25.8	57	1.11	45.43	4.5	Excellent
Solid Wall	35	S	M	23.6	79	0.73	60.6	4.3	Excellent
Solid Wall	35	S	A	27.4	81	0.91	28.1	4.1	Inadequate

W = winter; S = summer; A = afternoon; M = morning; PI = performance index.

Figure 4 shows the final user's screen. It displays the performance index in different colors related to the corresponding PI (Table 11) and a description of the input data.

App results screen

(**a**)

Description

Each row displays the performance index in different colors, birds' age and genetic strain, type of house, period, and season.

(**b**)

Figure 4. Screen showing the performance index results (**a**) and the data input details (**b**). Source: Developed by the authors.

4. Discussion

The present study proposed a mobile application using Python to follow up and forecast the performance of a broiler flock given the type of housing and rearing environmental conditions. This study used a robust database from four different types of houses and rearing environmental variables assessed.

When negative values were found for the Performance Index, it was an indication that variables were above or below the thermoneutral limits found in the literature [5,7,27–30].

By finding a set of parameters that led to a model, we could forecast whether the broiler chickens are reared adequately on farms. Although other attempts to automatically grade broiler performance have been reported in the current literature [19,20], the previous studies did not encompass flock evaluation in a broader aspect as we did. Since the present results were derived from historical field data, the forecast was more related to actual data, differing from experimental tests [31]. Silva et al. [32] proposed an App that assessed compliance with good practices of broiler production. Such an initiative would allow a farmer to audit a flock, controlling continuously how equipment and management were kept during the grow-out period.

In the present proposed mobile application, we forecasted in real-time and had an output response that gave a hint on how the flock was performing. We foresee the use of the App for farmers performing self-audits. By making a proper decision on time, a farmer might correct unhelpful trends, reducing or avoiding flock losses. Such a move can be made by simulating the input with changes in the ventilation rate, for instance, and confirming whether that input changed the final PI. If a broiler farm had a higher degree of technology applied, such as automated control panels, we believe that the App could be uploaded directly from the used systems and provide a response in real-time. However, this adaptation still needs to be upgraded.

The field of precision livestock farming has grown substantially in the last years [18,19,21]. The possibility of using automated models should significantly improve quality control in animal production. Further tool development will be required to guarantee efficient applications for farmer-support tasks.

An automatic survey of facilities' internal environmental conditions could be motivated by the systematic use of the App to assist decision making and real-time alarm. Our results showed that the App allowed the indication of flock performance using environmental data. The App assisted the process of visualizing the compliance of the rearing conditions, allowing farmers to take action. This action could make it possible to better understand the management and control practices of a farm's environment, helping the development of new technologies that would effectively add value to the production chain. Future connection to appropriate sensors and actuators might allow complete integration with open-source electronic components.

5. Conclusions

We developed a mobile application to help farmers evaluate the suitability of broiler rearing conditions during a flock's growth and grade the flock using a performance index. We believe such a tool could help broiler farmers follow up on their flocks and help decision making during growth in real-time.

For people who enjoy having a second opinion, the mobile application could serve as a random inspection by solely manual input, even for farms with a high degree of automation. However, the mobile application should be mainly used by small- and medium-sized poultry farmers in tropical regions who do not have access to high automation technology in their aviaries.

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Nomenclature

MT	Average temperature (°C)
MH	Average relative humidity (%)
MVa	Average air velocity (m/s)
MCO_2	Average concentration of carbon dioxide in the environment (ppm)
MNH_3	Average ammonia concentration in the environment (ppm)
niTH	Temperature vs. humidity normalized index
$niNH_3$	Normalized ammonia concentration index
niVar	Normalized airspeed index
$niCO_2$	Normalized carbon dioxide concentration index
PI	Performance Index
I	Age (d)
TempHum	Average temperature (°C) vs. relative humidity (%)
CTZ	Comfort zone temperature (°C) for broiler chickens
wTH	Weight for temperature vs. humidity normalized index
wNH_3	Weight for ammonia normalized index
wCO_2	Weight for carbon dioxide normalized index
wVar	Weight for air velocity normalized index
sumweight	Sum of the weights

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