



Article

Efficiency and Reliability of Broiler Weighing Methods in Commercial Environments: A Comparative Evaluation

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Abstract: Measuring the weight of broilers is one of the most important yet labor-intensive metrics to monitor throughout a flock's development. This study aimed to comparatively assess two broiler weighing systems in a commercial production system: an automatic weighing system using a suspended platform, and a manual weighing system. Six flocks, comprising 25,000 birds each, were monitored weekly, and the weight results obtained by manual and automatic methods were compared. Up to the third week of this study, the birds were restricted to the central region of the shed, where the broiler coop was located. From the fourth week onwards, the birds were distributed into four sectors within the shed, divided by fences. Differences in weight were found between the regions of the sheds for the automatic weighing, which demonstrates that the use of an automatic scale for each division is necessary. For the manual weighing, the differences were only found in the last week of rearing, suggesting that throughout the cycle, the weighings could be performed in a single quadrant, representing the shed. Regarding the weighing method, there were statistical differences between manual and automatic weighing. The average values for automatic weighing were 1% lower than the average values for manual weighing. However, from a commercial point of view, this small difference between the methods does not impact the poultry industry. The rational use of automatic scales is recommended to optimize the monitoring of broiler chicken performance, reduce excessive handling and, consequently, minimize animal stress, promoting greater well-being.

Keywords: broilers; weighing system; weight prediction; precision animal husbandry



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1. Introduction

Flock weighing is a fundamental practice in poultry farming, as it allows for the continuous monitoring of bird development. Although manual weighing is still widely used in commercial systems, it presents operational limitations. With advances in microelectronics, automated systems have been developed to optimize this process. However, the adoption of such technologies faces resistance and requires technical and scientific comparisons

with traditional methods. Therefore, it is necessary to evaluate the efficiency of different weighing systems available, considering current technological advancements [1].

Manual weighing, which predominates in commercial poultry farms, is considered inefficient due to the extensive time required per bird (averaging 7 to 27 s per animal—observational data), the physical effort demanded from the staff, and the stress caused to the birds by handling [2,3]. Additionally, it is prone to reading errors and sampling bias, especially due to the tendency to capture heavier and less agile birds [4,5].

Automatic weighing consists of one or more platforms connected to an analysis and/or data transfer unit. The birds voluntarily step onto the weighing platform and data are recorded. Some scales have technology to detect and differentiate the presence of one or more birds, as well as disregarding waste deposited on the weighing platform. Automatic weighing would allow for the continuous monitoring of the weight of the flock, without placing stress on the birds or requiring a high intensity of labor in order to obtain this information. One of the questions regarding weighing sampling is whether or not it is necessary to perform it in different areas in the shed. This is true for both the manual and automatic methods.

Despite technological advances in the automation of broiler weighing, there are still limitations regarding the reliability of the data generated, especially during the final stages of the rearing period. Previous studies have reported inconsistencies between weights obtained through automatic and manual methods, with divergent results in terms of accuracy and sample representativeness [1,3,6]. While some authors have found equivalence between weighing methods, others have observed the under- or overestimation of both the weights and the number of birds assessed automatically [7–10]. These discrepancies highlight the need for a systematic evaluation of the efficiency and reliability of different weighing methods in commercial environments, considering factors that may influence the quality of the data collected throughout the production cycle. Given the previously identified issues, we hypothesize that manual weighing differs from automatic weighing, and that weight variations exist across different regions of the shed.

The objective of this study was to evaluate the existence of discrepancies between manual and automatic weighing systems with the use of platforms in real production situations. Specifically, we want to (i) compare, at each stage of flock development, the results of automatic weighing technology with manual weighing, and (ii) analyze the effect of different regions of the shed on the live weight of the birds using manual and automatic scales.

2. Materials and Methods

2.1. Characterization of the Experimental Area and Animals

This research was developed on a commercial broiler farm located in the city of Itu—SP (23°19′02.0″ S 47°23′05.2″ W). The climate of the region is CWA according to the Köppen Classification. Two production cycles were evaluated.

This study was conducted in an agro-industrial production complex consisting of 10 poultry sheds (150 m long, 12 m wide, and 2.5 m high) and a blue house model, oriented in an east–west direction. The sheds had an automatic line of feeders and nipple drinkers. The adiabatic evaporative cooling system consisted of cellulose evaporative plates, with negative pressure through the use of eight exhaust fans on the transverse walls opposite to the direction of air intake in the facility. The distance between the sheds was 15 m. Production was characterized by an average density of 14 birds/m², totaling 25 thousand birds housed in each shed. Two complete production cycles were evaluated, with three sheds being evaluated in each cycle, totaling six sheds, and 150,000 mixed-sex Cobb and Hubbard Flex birds were used. Feeding was automated on three feeding

lines, ad libitum, according to the phases (pre-starter, starter, growth, and slaughter), and the vaccination and medication protocol was carried out in accordance with the company's guidelines.

2.2. Description of Weighing Systems

2.2.1. Automatic Weighing

Automatic weighing was performed continuously; however, for comparison between the average weight of the flock, the weighings related to the day of manual weighing were considered. The scale used for automatic weighing in this study was the BAT2 model (Veit Electronics[®], Moravany, Czech Republic). It had a maximum operational capacity of 100 kg, an accuracy of 0.1%, and a resolution of 1 g. The scale was programmed so that the weights were recorded when the birds climbed up and down the weighing platform. A weight correction curve was used with the addition of 7% according to previous experiences under commercial conditions (pilot test), higher than that recommended by the supplier.

Four automatic scales were installed in each shed, distributed along the length of the facility as shown in Figure 1. This distribution was not performed so that the platforms were equidistant. In this case, it was decided to centralize them on the partitions which previously existed in the shed due to the management with migration fences adopted by the producer. The scales were positioned between the line of feeders and drinkers.

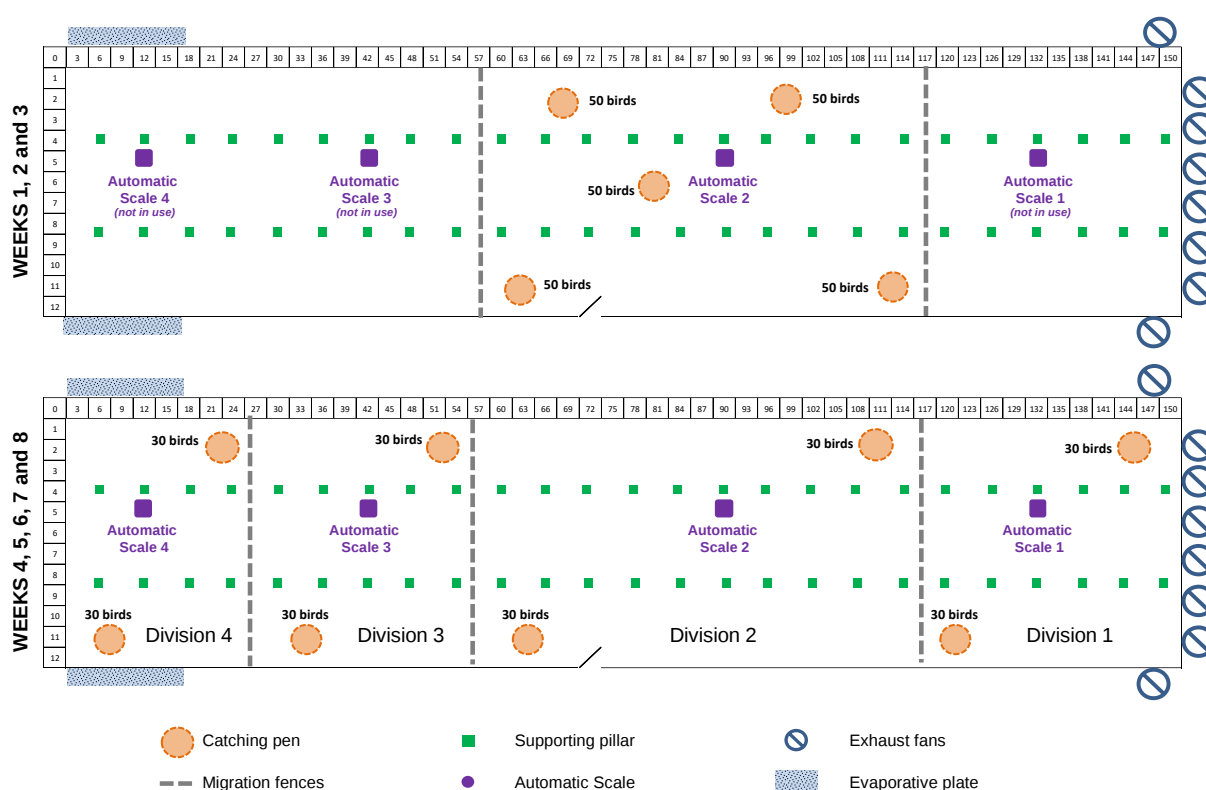


Figure 1. Positions of automatic scales and manual weighing in the stables.

It is worth noting that between 1 and 20 days, the birds remained only in Division 2, where the “chicken coop” was located. Therefore, only scale 2 of each shed was used during this period. As the flock grew, the area available for the birds increased, and consequently the number of scales that were used increased.

The location and use of the scales in the experimental area can be seen in Figure 2.

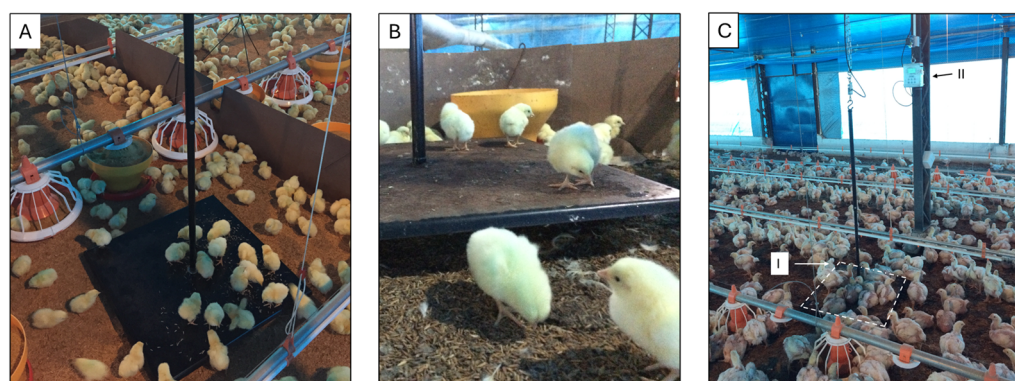


Figure 2. Scales installed in commercial sheds. (A) One-day-old birds on the weighing platform of the automatic scale. (B) Detail on the platform height (C). Twenty-eight-day-old birds on the weighing platform of the automatic scale, where I is the platform and II is the registration unit.

2.2.2. Manual Weighing

Manual weighings were performed weekly according to the growth of the birds, ending in the 7th week. It should be considered that the flocks were not all housed on the same day, thus presenting an age window between the flocks of each phase. Therefore, the weighings were planned to meet the demands of each flock. Since the housings were carried out on different days, in order to standardize the weighings every 7 days, there was an adjustment in the readings between the first and second week. Therefore, from the second week onwards, the weighings were performed at weekly intervals, as described in Table 1.

Table 1. Housing dates and weighing ages.

Flock	Weighing Ages
I	1; 10; 17; 24; 31; 38; 45
II	1; 10; 17; 24; 31; 38; 45
III	1; 9; 16; 23; 30; 37; 44
IV	1; 8; 15; 21; 28; 36; 42
V	1; 8; 15; 21; 28; 36; 42
VI	1; 8; 15; 21; 28; 36; 42

The BAT1 digital scale (Veit Electronics) was used for manual weighing. The maximum operational capacity was up to 50 kg and the resolution was 1 g.

According to the age group of the birds, different handling methods were adopted to adapt to their characteristics, using plates and bags for weighing as follows (Figure 3):

- Weighing plate—1st to 3rd week;
- Weighing bag—4th to 7th week.

Manual weighing always occurred in the quadrant where the automatic scale was installed. Weighing management followed the changes that commonly occur in a production system, according to the opening of the brooders. These, in turn, are opened and released according to the development of the birds. Therefore, the spatial variability of manual weighing positioning followed this management. The distribution layout of the automatic scales and manual weighing positions can be seen in Figure 1.

It should be considered that there was a weekly adjustment depending on the opening of the breeding circles and their age. The general scheme of animals sampled during the production cycle can be seen in Table 2.

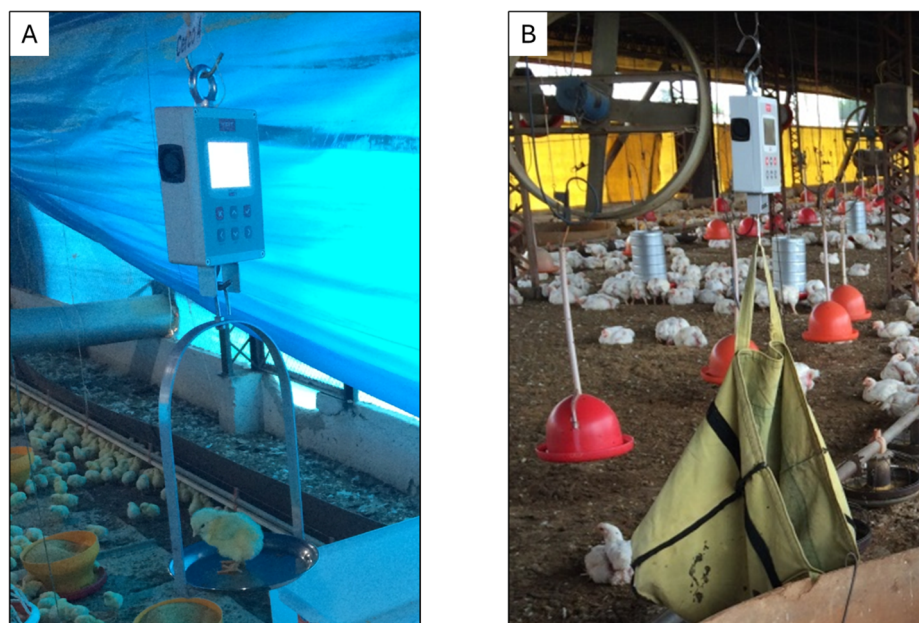


Figure 3. Weighing methodology. (A) One-day-old bird being weighed on a suitable plate. (B) Twenty-eight-day-old bird being weighed in a bag.

Table 2. Sampling used according to bird age.

Age	Collection Points and Number of Birds	Total Sample per Shed
Day 1	500 animals in the pen	500
Up to the 20th day	5 points with 50 animals each	250
From the 21st day	4 quadrants $\times$ 2 points $\times$ 30 animals each	240

The decision to adopt 30 birds per measurement point was based on a previous experience (pilot test), in which all the fenced birds were initially weighed at the time of weighing. After preliminary analyses of these data (variance stabilization analysis), it was concluded that it was not necessary to collect data from all fenced birds. Therefore, 30 birds were evaluated per weighing point.

2.3. Statistical Methods

In order to study the divisions in animal performance, a completely randomized design was adopted for the division variables from the fourth week onwards. Each weighing in each division during the week was considered a repetition. First, the assumptions of data normality and homogeneity of variance were tested using the Kolmogorov–Smirnov (normality) and Box–Cox (homoscedasticity) tests. Thus, the dependent variables, weight and temperature, were transformed in order to stabilize the variance. After that, an analysis of variance (ANOVA) was performed to test the hypotheses at a probability level of 95%. The ANOVA was performed using the GLM (General Linear Models) procedure of the SAS 9.3, 2011 (Statistical Analysis System) statistical program, considering the Sum of Squares type III due to the sample imbalance for all designs. Finally, a Tukey–Kramer mean comparison test was performed, at a probability level of 95%, to determine in which treatment there is a difference between the estimated means, if the ANOVA indicated a significant difference between the treatments for each situation studied.

To represent the structure of the statistical analysis, the following equation describes the general linear model (GLM) applied in the analysis of variance:

$$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$$

where Y_{ij} = observed value of the dependent variable (weight or temperature) in the i th division and j th repetition; μ = overall mean; α_i = fixed effect of the i th division; and ε_{ij} = random error associated with each observation, assumed to be normally distributed with mean zero and constant variance, $\varepsilon_{ij} \sim N(0, \sigma^2)$.

3. Results and Discussion

The highest frequency of weighings was recorded in the second week (2385 records), while the lowest occurred in the seventh week (718 records). A decreasing linear trend was also observed in the number of birds accessing the platform over the weeks.

3.1. Comparative Analysis of Shed Regions

There were differences ($p < 0.005$) between the partitions of the broiler sheds in all divisions from the 4th to 7th week when the birds were weighed with automatic scales. The opposite was observed for the birds weighed with manual scales, in which the weights between the partitions were similar ($p > 0.05$) in the weeks evaluated, with the exception of the last week of evaluation (Table 3).

Table 3. Average automatic and manual weight per week according to spatial variability of partitions (data from grouped phases from barn 2).

Week	Automatic				Manual			
	Partitions				Partitions			
	1	2	3	4	1	2	3	4
4	0.877 a	0.866 a	0.874 a	0.861 a	0.864 a	0.881 a	0.858 a	0.869 a
5	1.403 b	1.400 b	1.432 a	1.406 b	1.425 a	1.423 a	1.403 a	1.432 a
6	2.033 b	2.025 b	2.067 a	2.054 a	2.048 a	1.998 a	2.081 a	2.044 a
7	2.524 bc	2.507 c	2.545 ab	2.557 a	2.508 c	2.509 bc	2.637 ab	2.698 a

Equal lowercase letters correspond to statistically equal values in the same row according to the Tukey–Kramer test at a significance level of 5%, analyzed separately for automatic and manual weighing.

This result is explained by the difference in the sample size of these two methods, since manual weighing collected 60 birds in each division and automatic scales easily reached the mark of 1000 daily records. However, it is worth noting from a commercial point of view that the differences between the maximum and minimum values between the partitions are small, except in the last week, which would not have an impact on the poultry industry, although there is a statistical difference between the partitions of the sheds, especially in the automatic case.

The lower weights of the birds in division 4, both in the sheds with automatic or manual scales, can be explained by the higher air temperature in division 4 (Table 4), which possibly caused thermal stress in the animals, affecting their performance [11].

Table 4. Average air temperature in broiler houses in different partitions.

Shed	Temperature in partitions (°C)				p-Value
	1	2	3	4	
1	27.281 a	26.737 a	25.503 b	24.498 c	<0.0001
2	27.413 a	26.528 b	25.486 c	24.198 d	<0.0001
4	28.477 a	27.361 b	25.764 c	24.558 d	<0.0001

Equal lowercase letters correspond to statistically equal values in the same row according to the Tukey–Kramer test at a 5% significance level.

This thermal variability in negative pressure ventilation sheds is quite common. Nascimento et al. [12] found a thermal difference between quadrants of negative pressure

ventilation poultry houses, i.e., spatial thermal heterogeneity. Miragliotta et al. [13] also observed high spatial thermal variability in the shed, similar to what was found in this study. The authors Menegali et al. [14] and Damasceno et al. [15] commented on the inefficiency and thermal heterogeneity throughout the negative pressure ventilation system sheds for broilers. Even though partitions 4 and 3 had the lowest house temperatures compared to the others, it is worth noting that these were outside the ideal ranges (22 °C) [15]. When broilers are within the thermoneutral zone, they present higher production rates (weight gain, feed conversion, etc.) [16–18].

In general, based on the data presented in Table 3, it can be concluded that there were no statistical differences in the positioning of the dividers in the manual weighing, except in the 7th week. On the other hand, in the automatic weighings there were differences in all dividers and in all weeks, evidencing that this weighing method is more sensitive to identify common weight variability across the shed. Therefore, it is suggested that one automatic scale is not sufficiently representative of a flock and that platforms should also be placed in the different quadrants of a shed.

3.2. Comparison Between Manual and Automatic Weighing Results

The comparison between the weights obtained by the manual and automatic methods was performed at the ages at which the manual weighings occurred, as described in Table 1. For all ages, with the exception of weights in week 5, there was a statistical difference between the weights obtained by automatic and manual weighing. The results are described in Table 5.

Table 5. Average weights (kg) obtained by manual and automatic weighing.

Age (Weeks)	Weighing Type (kg)		<i>p</i> -Value	Weighing Difference (kg) (PA-PM)	Variation (%)
	Automatic	Manual			
1	0.044	0.040	$p < 0.05$	+0.004	+10
2	0.169	0.174	$p < 0.05$	−0.005	−3
3	0.447	0.454	$p < 0.05$	−0.007	−2
4	0.880	0.867	$p < 0.05$	+0.013	+1
5	1.419	1.419	NS	0.000	0
6	2.054	2.072	$p < 0.05$	−0.019	−1
7	2.531	2.582	$p < 0.05$	−0.051	−2
Average	1.087	1.078	$p < 0.05$	−0.009	−1

The largest discrepancy occurred in the 1st week of evaluation (+10%), while in the 5th week, the measurements coincided (0%). This variation can be attributed to the lower accuracy of manual scales when weighing young animals, whose reduced body weight amplifies small absolute differences in relative terms. Furthermore, manual handling is more prone to operational errors, such as animal instability, inaccurate readings, or inadequate calibration. The progressive adaptation of the animals to the automatic scale may have also contributed to the reduction in variations over time. The convergence of values in the following weeks reinforces the reliability of the automatic scales, especially after the initial adaptation phase, with the potential to enhance the accuracy of zootechnical data, minimize animal stress, and streamline management.

These results are in agreement with Newberry et al. [2] and Blokhuis et al. [7], who concluded that the average weight obtained automatically was lower than that obtained manually. However, Schomburg et al. [8] compared automatic and manual weighing, observing that automatic weighing overestimated the number of animals due to occasional problems with system recalibration, which resulted in measured weights greater than the actual weights. However, other authors found results contrary to this work, such as Turner

et al. [1,6] and Doyle and Leeson [3], who found no statistical differences between automatic and manual weighing. These research results should be considered in the way in which they were performed, whether on laboratory or production scales, and especially in the particularity of the equipment evaluated. However, some researchers obtained different results for manual and automatic weighing.

Vranken et al. [19], when comparing automatic weighing with manual weighing, found reductions of 1%; 14%; 4%; −6%; −2%, and −14% for the 2nd, 3rd, 4th, 5th, 6th, and 7th weeks, respectively. The authors did not describe whether or not they used any correction curves. These authors sought to use image analysis in conjunction with the automatic scale to create an algorithm that would help provide a better estimate of flock weight and obtained an error of 5% more than manual weighing in the 7th week.

4. Conclusions

Manual and automatic weighings showed slight differences in the weighing of birds. Although there were statistical differences between sections of the barn in weeks 4, 5, and 6, these do not compromise management decisions, allowing for the recommendation of using the automatic scale in a representative quadrant during these phases. However, in the final week of production, when weight precision is crucial for commercial and slaughter decisions, it is essential to have a scale in each quadrant, regardless of the weighing method.

Thus, the rational use of automatic scales can optimize the monitoring of broiler performance, reduce excessive handling, and consequently minimize animal stress, promoting greater welfare. Additionally, standardizing the use of scales at strategic points in the barn contributes to the technological efficiency of the production system, combining data accuracy with reduced operational costs and improved decision-making.

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Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author(s).

Conflicts of Interest: Author Pasian is a former employee of Elanco Animal Health. Author Reple works for Elanco Animal Health. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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